SG-99-01-002

SOUTH TEXAS UNIT - 2

CYCLE 7 VOLTAGE-BASED REPAIR CRITERIA REPORT

January 1999

Westinghouse Electric Corporation
Energy Systems Business Unit
Nuclear Services Division
P.O. Box 158
Madison, Pennsylvania 15663-0158

SG-99-01-002

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Cycle 7 Voltage-Based Repair Criteria Report

1.0 Introduction

This report provides a summary of the South Texas Unit-2 steam generator (SG) bobbin and rotating pancake coil (RPC) probe inspection at tube support plate (TSP) intersections, together with postulated steam line break (SLB) leak rate and tube burst probability analysis results, in support of implementation of a voltage-based repair criteria for Cycle 7 as outlined in the NRC Generic Letter 95-05 (Reference 9-1). A 1.0-volt repair criterion for outside diameter stress corrosion cracking (ODSCC) indications at the TSP intersections is being implemented for the first time starting with the current cycle (Cycle 7) for Unit-2. Information required by the Generic Letter is provided in this report including SLB leak rates and tube burst probabilities calculated using the end of cycle (EOC) conditions for the last cycle (Cycle 6) and projection of bobbin voltage distributions, leak rates and burst probabilities for the EOC-7 conditions.

Analyses for Cycle 6 were carried out using the actual bobbin voltage distributions measured during the EOC-6 outage and the results compared with corresponding results from projections based on the EOC-5 bobbin voltage data presented in the technical report submitted to justify the 1.0-volt repair criteria (Reference 9-2). Westinghouse generic methodology based on Monte Carlo simulations presented in Reference 9-3 was used in these evaluations, and this methodology was also utilized for the analyses performed for Unit-1 after its recent outage (Reference 9-6).

Analyses were also performed to project leak rates and tube burst probabilities for postulated SLB conditions at the end of the ongoing cycle (Cycle 7) based on the 1.0 volt repair criteria. These analyses utilized bobbin voltage distributions measured during the recent (EOC-6) inspection and a limiting growth rate distribution from the last two inspections (EOC-5 and EOC-6 inspections).

Two other supplemental evaluations are also presented in this report. One of them examines probability of detection for Cycle 5 inspection (probability of prior cycle detection – POPCD) and the other assesses the fraction of the indications that showed no degradation during the RPC inspection in 1997 (EOC-5 inspection), were left in service at beginning of Cycle 5 (BOC-5), and were RPC confirmed in 1998 at EOC-6.

Two tube segments (R18C100 and R19C83) in SG-A each with 4 TSP intersections (TSP 1 – flow distribution baffle (FDB) – and TSPs 2 to 4) were pulled during this inspection for detailed laboratory examination. Results from leak and burst tests and metallurgical examination are presented in Section 3. Eddy current and repair data for EOC-6 TSP indications are provided in Section 4. The leak and burst databases applied and the Monte Carlo analysis used to estimate leak rate and tube burst probability are briefly described in Sections 5 and 6. The actual EOC-6 voltage distributions as well as leak rates and tube burst probabilities calculated for these distributions are compared with the projections for EOC-6 conditions (performed using the EOC-5 data) in Sections 7 and 8. Leak rates and burst probabilities for the projected EOC-7 voltage distributions are reported in Section 8 and compared with allowable limits.

2.0 Summary and Conclusions

A total of 1485 indications were found in the EOC-6 inspection of which 40 were over 1 volt and 6 of these 40 indications were above 2 volts. Thirty-nine of the 40 indications over 1 volt were found on the hot leg side and one indication on the cold leg side. Forty-four TSP indications, including all 39 indications on the hot leg side over 1 volt, were inspected with an RPC probe and 34 were confirmed as flaws. The single cold leg indication over 1 volt was not RPC inspected, but was treated as a RPC-confirmed indication and repaired; this indication is further described in the paragraph below. SG-B had the largest number of indications among the four SGs with 500 bobbin indications; however, SG-A had the highest number of indications above 1.0 volt, and it also had the 4 largest indications found during this inspections, all above 2 volts. All 11 indications above 1.5 volts and 23 out of 28 indications between 1.0 to 1.5 volts inspected by RPC probe were confirmed as flaws and were repaired. No ID or circumferential indications at the TSP intersections, or indications extending outside the TSP were found in this inspection. A total of 47 TSP intersections in all 4 SGs combined with a mixed residual signal that could potentially mask a 1.0 volt bobbin indication (residual signal voltage 1.5 volts or greater) were inspected with a RPC probe and 4 of them were found to contain single axial indications (SAIs), and they were repaired.

In SG-C, the bobbin signal for the first pre-heater baffle plate intersection on the cold side (22C) in tube R1C102 was initially called as a wear indication and was assigned 2.05 volts. A later reexamination of this bobbin signal indicated that it may be a potential crack-like signal and its voltage was revised to 1.23 volts. As a crack and potential ODSCC indication subject to GL 95-05 requirements, the indication would be required to be RPC inspected. By the time this reassessment was completed, equipment needed for RPC examination of this intersection had been removed from the steam generator. Based on discussions with the NRC, it was concluded that the RPC inspection could be omitted and this tube (R1C102) was repaired, which is equivalent to assuming RPC confirmation of the indication as a crack-like flaw rather than wear. To ensure proper classification of cold leg indications in future inspections, all pre-heater baffle plate intersection indications on the cold leg side will be inspected with an RPC probe. Both bobbin and RPC data will be used to classify the indications as ODSCC or wear. Indications extending outside these baffle plate intersections will also be RPC inspected.

SLB leak rate and tube burst probability analyses were performed for the actual EOC-6 bobbin voltage distributions as well as the projected EOC-7 bobbin voltage distributions. The analysis took credit for the availability of pressurizer PORVs by using a primary-to-secondary pressure differential of 2405 psid for the design-basis SLB event. The actual number of indications detected during the EOC-6 inspection are about 12% to 42% below the corresponding projections performed using the EOC-5 data and POD=0.6 for all SGs except SG-C for which the actual number is about 5% higher than the projected number of indications. While the peak EOC-6 voltage measured for SG-B was below the value projected, 4 indications in SG-A and 1 each in SGs C and D exceeded the peak voltage projected for them. Because of detection of a 4.1 volt indication in SG-A, the leak rate and tube burst probability based on the actual voltages are higher than projected for that SG. However, the absolute magnitude of the SLB leak rate (4.6×10^{-4} to 3.2×10^{-2}) and tube burst probability (1.2×10^{-5} to 3.8×10^{-4}) values based on the actual conditions are small, and they are almost 2 orders of magnitude below the acceptance limits (15.4 gpm at room temperature and 10^{-2}) for all 4 SGs.

The leak rate and tube burst probability projections at the EOC conditions for the current cycle (Cycle 7) are also well within their acceptable limits. The limiting SLB leak rate projected for the EOC-7 conditions using the standard analysis methodology (Reference 9-3) and a constant POD of 0.6 is 0.033 gpm. This value is projected for SG-A which had the largest indication found in the EOC-6 inspection, and it is more than 2 orders of magnitude below the allowable EOC-7 leakage limit of 15.4 gpm (room temperature). The highest tube burst probability, 4.2×10^{-4}, is also predicted for SG-A, and it is more than a decade below the NRC reporting guideline of 10^{-2}. Two sensitivity analyses were also performed for the limiting SG (SG-A). The EOC-7 projection for SG-A was repeated using leak and burst correlations updated to include new data from the tube specimens pulled during the present inspection. While the EOC-7 tube burst probability did not change significantly, the SLB leak rate increased from 0.033 to 0.045 gpm. The Cycle 6 growth data for SG-A appear to show a dependency on the beginning of cycle (BOC) voltage. Therefore, EOC-7 projections for SG-A were also repeated using the methodology recommended in Reference 9-4 to account for growth dependency on BOC voltage. The projected EOC-7 leak rate increased from 0.033 to 0.040 gpm and tube burst probability increased from 4.2×10^{-4} to 5.5×10^{-4}. The magnitude of increase in SLB leak rate and tube burst probability in the above two sensitivity analyses are small in comparison to the margins available to their respective acceptance limits. Thus the GL 95-05 requirements for continued plant operation for the projected duration of Cycle 7 are met.

As the magnitudes of the projected EOC-7 leak rates and tube burst probabilities are very small, there is some potential for the leak and burst results based on the actual EOC-7 conditions to exceed their projections. As in Cycle 6, occurrence of just one indication in the modest voltage range of 3 to 4 volts, which is not considered highly improbable, can result in the actuals exceeding their projections. However, even if the SLB leak rates and tube burst probabilities for the actual EOC-7 conditions exceed their projections by a factor of 5 to 10, they would still be an order of magnitude below their respective limits.

Probability of detection (POPCD) for the EOC-5 inspection was assessed using EOC-5 and EOC-6 inspection data. Although a voltage-based repair criterion was not applied at EOC-5, the eddy current data were evaluated using the same procedures as applied to plants using voltage-based repair criteria. Therefore, EOC-5 inspections can be used for POPCD evaluation. The results support a detection probability greater than the NRC mandated value of 0.6. Four indications with no degradation found (NDF) by RPC during the EOC-5 inspection were tested again in the EOC-6 inspection and 3 were confirmed yielding a RPC confirmation rate of 75%. Currently, the database for the RPC confirmation rate for prior cycle NDF indications in the South Texas units is too small to recommend a confirmation rate for use in the projection analyses. All RPC NDF indications are included in the EOC-7 projections presented in this report.

3.0 South Texas Unit-2 1998 Pulled Tube Data for TSP Locations

3.1 South Texas Unit-2 Pulled Tube Examination Results

3.1.1. Introduction

Two tubes removed from SG-A of South Texas Unit 2 (R18C100 and R19C83) were examined in a hot cell at the Westinghouse Science and Technology Center. The pulled tube segments included the following areas of interest for TSP intersections from each tube: first tube support plate (TSP-1 or FDB), and the TSP-2, TSP-3 and TSP-4 locations. Prior to tube removal, field eddy current inspections showed potential indications (PI) by bobbin probe at the TSP-2 and TSP-3 locations of Tube R18C100 and at the TSP-2 location of Tube R19C83. Field 80 mil pancake coil single axial indications (SAI) were observed at each of these locations. In addition, the TSP-3 region of tube R19C83 had a PI call from the bobbin data, but not the pancake coil data. The FDB and TSP-4 regions of R19C83 were retained as archive samples and were not destructively examined.

3.1.2. Nondestructive Examinations

The tube sections were inspected in the laboratory by eddy current using techniques similar to those used during the field inspection. The tubes had been cut in the field into lengths between 23 and 34 inches long to allow the tube segments to be removed from the steam generator and to fit into a shipping container. Specifically four sections of each tube were inspected using a 0.610 inch diameter differential bobbin coil probe, and a Zetec +Point probe. The inspected tube sections were associated with the TSP-1, TSP-2, TSP-3 and TSP-4 locations. The data were collected using a R/D Tech TC 6700 and recorded on Optical disks. Analyses of the data were conducted using the Westinghouse Anser system.

A review of the field eddy current data for the removed tubes showed essentially no difference between the original field calls and the review of the data. Table 3-1 summarizes the eddy current results for the areas of interest. Note that the +Point results are for the 300kHz channel and that the bobbin coil results are for the 550/130 kHz MIX channel. The table shows the presence of a large indication at the TSP-3 location of Tube R18C100 and at the TSP-2 location of Tube R19C83 as noted by both bobbin and +Point data. A smaller indication was noted by both bobbin and +Point data at the TSP-2 location of Tube R18C100. At the TSP-3 location of Tube R19C83, only a bobbin indication was noted.

The laboratory eddy current data showed the same indications as in the field data with a small increase in eddy current voltage for the large indication at

TSP-3 of Tube R18C100 and a large increase in eddy current voltage for the TSP-2 of Tube R19C83 over that of the field results. This increase suggests the possibility that noncorroded ligaments present between individual corrosion microcracks had separated during the tube removal for these two locations. The bobbin coil indication identified at the TSP-3 location of Tube R19C83 was a distorted indication that could be a tube deposit response rather than a response from corrosion degradation. However, the guidelines for NDE analyses to support voltage-based repair criteria recommend calling this type of indication as a potential indication for RPC inspection, which is consistent with the field call.

3.1.3. Leak, Burst and Tensile Data

Following NDE testing, elevated temperature leak testing was performed on the two large voltage indications (TSP-3 of Tube R18C100 and TSP-2 of Tube R19C83). Both specimens developed leaks at all of the tested differential pressures designed to simulate conditions ranging from normal operating conditions (NOC) to steam line break (SLB) conditions. Actual differential pressures ranged from a minimum of 1325 psi to 2581 psi. Table 3-2 provides a summary of test conditions and measured leak rates for the various test conditions. The TSP-3 region of Tube R18C100 had a smaller leak rate at NOC than did the TSP-2 region of Tube R19C83. However, exposure to higher differential pressures apparently caused ductile ligament rupture to the extent that subsequent leak rates were higher for the TSP-3 region of Tube R18C100 than for the TSP-2 region of Tube R19C83. Later SEM fractographic data showed that the crack network for the TSP-3 region of Tube R18C100 was very complex with two or three throughwall cracks that probably interconnected during leak testing. Measured leak rates ranged from 0.000145 gpm at NOC to 0.033 gpm at SLB conditions for TSP-3 of Tube R18C100 and from 0.000792 gpm at NOC to 0.0185 gpm at SLB conditions for TSP-2 of Tube R19C83.

Following leak testing, sections of both tubes were burst tested at room temperature. The TSP-1, TSP-2, TSP-3 and TSP-4 locations of Tube R18C100 and the TSP-2 and TSP-3 locations of Tube R19C83 were burst tested along with a control free span (FS) section of each tube without NDE indications. Table 3-3 presents a summary of the burst data. All burst pressures were well above safety limitations required by R.G. 1.121 with the two large voltage indication locations having the lowest burst pressures: 5,006 psi for TSP-3 of Tube R18C100 and 5,958 psi for TSP-2 of Tube R19C83. The TSP-2 region of Tube R18C100 was the only other burst specimen with an obviously reduced burst pressure: 7,196 psi burst pressure.

A visual examination performed on the burst tested specimens showed no corrosion on the single FDB region burst tested (TSP-1 of Tube R18C100), and corrosion present on all true TSP regions (TSP-2, TSP-3 and TSP-4 of Tube R18C100 and TSP-2 and TSP-3 of Tube R19C83). The corrosion observed on the TSP regions was entirely confined to the TSP crevice region. The TSP-4 region of Tube R18C100 had only field and laboratory NDD calls and a burst pressure and ductility similar to that of its FS control specimen. The TSP-3 region of Tube R19C83 had only a small bobbin PI and a burst pressure and ductility similar to its FS control specimen. It is judged that the corrosion present at these two locations was shallow, probably on the order of 10% deep. It was decided to destructively examine only the three specimens with reduced burst pressures: the TSP-2 and TSP-3 region of Tube R18C100 and the TSP-2 region of Tube R19C83. Figures 3-1, 3-2 and 3-3 provide sketches of the burst openings and of the secondary corrosion observed on the three specimens chosen for destructive examination. Note that the TSP-3 region of Tube R18C100 had a complex burst opening. It will be more completely described in the next section.

Finally, Table 3-3 includes room temperature tensile test data obtained on additional FS sections from both tubes. The tensile properties appear typical of MA Alloy 600 steam generator tubing of this vintage.

3.1.4. Destructive Examinations

SEM fractography was performed on each of the burst opening fractures faces chosen for destructive examination: the TSP-2 and TSP-3 region of Tube R18C100 and the TSP-2 region of Tube R19C83. Table 3-4 presents a summary of the results in the form of crack depth profiles and ductile ligament data. The TSP-2 region of Tube R18C100 and the TSP-2 region of Tube R19C83 had simple axial burst openings. The TSP-3 region of Tube R18C100 had a complex "H" shaped burst opening that formed from two close-by parallel axial corrosion macrocracks. These two cracks joined by a tearing through a region of intergranular corrosion that separated the two axial macrocracks. Table 3-4 provides the crack profiles for both of these two parallel axial corrosion macrocracks. The horizontal bar of the "H" shaped region was not characterized by fractography. However, the horizontal bar was measured as approximately 0.1 inch long, while the two parallel macrocracks were approximately 0.64 and 0.38 inch long.

Each of the four axial burst fracture faces (one each from TSP-2 of Tubes R18C100 and R19C83 and the two fracture faces from TSP-3 of Tube R18C100) had OD origin intergranular corrosion that occurred as a macrocrack composed of a number of OD intergranular microcracks joined together by ligaments. Most of these ligaments had only or mostly intergranular features, indicating that these particular ligaments grew together during plant operation. Each of the four burst corrosion macrocracks also had ligaments with predominantly ductile features, indicating that these particular ligaments formed (tore) during either tube pulling, leak testing, burst testing, or subsequent laboratory handling. The two macrocracks from TSP-3 of R18C100 also had ductile ID lips that probably acted similar to ductile ligaments.

The largest corrosion macrocrack was the left-hand crack of the "H" shaped crack network for the TSP-3 region of Tube R18C100. It was 0.637 inch long, averaged 68% deep, was 100% throughwall over 0.045 inch and 98% deep (ID tensile lip on fracture) over another 0.135 inch. The right-hand crack of the network was at least 0.38 inch long (mechanical damage at the bottom of the crack prevented exact length determination, but burst photographs suggested a crack length of 0.38 inch), averaging 79% deep over the 0.325 inch with fractographic data, was 100% throughwall over $\geq$ 0.155 inch and 97% deep (ID lip on fracture) over another 0.032 inch. (Again, these two parallel axial macrocracks were joined together during burst testing (possibly during leak testing) by a 0.1 inch long horizontal crack.)

The TSP-2 region of Tube R19C83 was 0.436 inch long, averaged 77% deep and was 100% throughwall over 0.2138 inch. The TSP-2 region of Tube R18C100 was 0.621 inch long, had a maximum depth of 93% throughwall and averaged 55% throughwall.

Based on the appearance of the cracks examined by SEM, it is believed that the corrosion morphology was composed primarily of axial intergranular stress corrosion cracking (IGSCC) with some intergranular cellular corrosion (ICC) also present. ICC is a crack structure composed of a mixture of axial, circumferential and oblique angled IGSCC. It is further suggested that the OD intergranular corrosion present is typical of that in the EPRI data base gathered in support of alternate plugging criteria.

3.1.5. Summary

The true TSP crevice regions of Tubes R18C100 and R19C83 had OD intergranular corrosion. The FDB (TSP-1) regions did not have corrosion. The TSP-3 region of Tube R18C100 and the TSP-2 region of Tube R19C83 had throughwall corrosion. Leak testing for these two specimens produced leak rates that ranged from a low of 0.000145 gpm at NOC (TSP-3 of R18C100) to a high of 0.033 gpm at SLB conditions (TSP-3 of R18C100). Burst testing showed that the corroded TSP regions all had strength properties exceeding regulatory guidelines. Of the remaining three true TSP regions, one (TSP-4 of R19C83) was archived after NDE examination and the other two were burst tested without performing destructive examinations. Visual inspection of these two TSP regions (TSP-4 of R18C100 and TSP-3 of R19C83) showed that intergranular corrosion was present. From their apparently unaffected burst properties, it is assumed that their corrosion depth was probably on the order of 10% throughwall. No field eddy current detection would be expected for corrosion of this depth. No degradation was called by eddy current for the TSP-4 region of R18C100, while a small voltage PI was called by bobbin inspection for the TSP-3 region of R19C83 (NDD field pancake coil and laboratory +Point call).

3.2 South Texas Unit-2 Pulled Tube Evaluation for Voltage-Based Repair Criteria Application

The pulled tube examination results were evaluated for application to the EPRI database for ARC applications. The eddy current data were reviewed, including reevaluation of the field data, to finalize the voltages assigned to the indications and to assess the field NDD calls for detectability under laboratory conditions. The data for incorporation into the EPRI database were then defined and reviewed against the EPRI outlier criteria to provide acceptability for the database.

3.2.1 Eddy Current Data Review

Table 3-5 provides a summary of the eddy current data evaluations for the South Texas Unit-2 pulled tubes. These NDE data results have been discussed in the above Section 3.1.2. As noted above, the field and laboratory reevaluations of the field bobbin data are in very good agreement for both voltage magnitudes and NDD calls. The reevaluated field bobbin voltages, including the adjustment for cross calibration of the field ASME standard to the laboratory standard, are used for the EPRI ARC database. The reevaluation was performed by the same analyst that performed a large part of the EPRI pulled tube database and the use of these voltages minimizes analyst variability in the database, which is separately accounted for in ARC applications as an NDE uncertainty.

The post-pull laboratory inspection results show a 30% increase in bobbin voltage for R18C100, TSP-3 and almost a factor of two increase in bobbin and +Point voltage for R19C83, TSP-2. These increases tend to indicate that some ligaments likely tore during the tube pulling operation. However, increases of these magnitudes in the bobbin voltage are not unusual and do not impact the use of the data for the ARC correlations.

3.2.2 South Texas Unit-2 Data for ARC Applications

The pulled tube leak test, burst test and destructive examination results are summarized in Table 3-6. The leak rates in this table have been adjusted to the reference conditions using the EPRI leak rate adjustment procedure commonly applied for data in the ARC database. Both R18C100, TSP-3 and R19C83, TSP-2 were found to have modest leak rates at normal operating and SLB conditions. Leak rate data are given in the table for SLB pressure differentials of 2405 and 2560 psi. The 2405 psi leak rates are applicable to South Texas-2 ARC analyses due to applicability of the PORVs for limiting the accident condition pressure differential. Although the indication at TSP-2 of R19C100 was not leak tested, it can be inferred that this indication would not leak at SLB conditions. The maximum depth of the indication is 93% and more than 90% deep only over about a 0.03" length. No ODSCC indications that have been leak tested in the ARC database at depths less than about 98% have been found to break through to throughwall at SLB conditions with resulting leakage. The short length of the deeper part of the indication supports an insignificant likelihood of break through and leakage at SLB conditions. Even a throughwall indication of 0.03" length would not leak at SLB conditions. Therefore, this indication can be included as a non-leaker in the probability of leakage correlation.

The South Texas Unit-2 pulled tube results were evaluated against the EPRI data exclusion criteria for potential exclusions from the database. Criteria 1a to 1e apply primarily to unacceptable voltage, burst or leak rate measurements and indications without leak test measurements. Criteria 1a to 1e are not applicable to the South Texas Unit-2 indications. Criterion 3 applies to potential errors in the leakage measurements and is not applicable to the South Texas Unit-2 indications since there are no known errors in the measurements and the leak rates are not low relative to leak rate correlations.

EPRI Criterion 2a applies to atypical ligament morphology for indications having high burst pressures relative to the burst/voltage correlation and states that high burst pressure indications with ≤ 2 uncorroded ligaments in shallow cracks < 60% deep shall be excluded from the database. Table 3-6 identifies the number of remaining ligaments and the maximum depths for the indications. The three indications destructively examined have maximum depths > 60% and Criterion 2a is not applicable. However, the R19C83, TSP-3 indication does not have destructive exam data to define the crack profile and the presence or absence of ligaments cannot be determined. The burst pressure for this indication is high on the burst correlation and Criterion 2a could be applicable if the crack profile was available for assessment. Since the destructive exam profile is not available for this indication to permit evaluation against Criterion 2a, the indication is excluded from the ARC database and is not used for either the burst pressure or probability of leak correlation.

As shown in the last column of Table 3-6, the TSP-2 indication of R18C100 is to be included in the probability of leakage and burst correlations. The indications at R18C100, TSP-3 and R19C83, TSP-2 are included in the burst, leakage and probability of leakage correlations. The R19C83, TSP-3 is excluded from the database per EPRI exclusion Criteria 2a due to lack of a destructive exam profile to assess the indication. The impact of the indications on the ARC correlations is further discussed in Section 3.4.

3.3 Comparison of South Texas Unit-2 Data with the EPRI Database

This section reports on the evaluations performed utilizing the leak rate and burst pressure test data described in the previous section. The data obtained from the tests are compared to the reference EPRI database for nominal 3/4" by 0.043" SG tubes as identified in Reference 9-4. The NRC staff concurred that the recommended database was appropriate for use via Reference 9-5. The results of the destructive examinations of the tube sections are delineated in the previous two sections (Sections 3.1 and 3.2). Those results revealed no information that would lead to a conclusion that the data should not be included in the database.

This section presents results from the evaluations carried out to examine the effects of including the leak rate and burst pressure test results from the South Texas Unit-2 pulled tube specimens on the reference database probability of leak, leak rate, and burst pressure correlations to the bobbin amplitude. In summary, the test data are consistent with the database relative to the probability of leak, the leak rate, and the burst pressures as a function of the bobbin amplitude. These comparisons and evaluations are discussed below. Furthermore, the resulting correlations based on including the data in the database should be considered to be applicable to the use of voltage-based repair criteria for indications in 3/4" diameter tubes in Westinghouse SGs.

3.3.1 Burst Pressure vs. Bobbin Amplitude

The results from the burst tests, performed on tube specimens which exhibited a non-zero bobbin amplitude at a TSP elevation location, were considered for evaluation. A plot of the burst pressures of the South Texas Unit-2 specimens is depicted on Figures 3-4 and 3-5 relative to the burst pressure correlation developed using the reference database.

1. A visual examination of the data relative to the EPRI database indicates that the measured burst pressures fall within the scatter band of the reference data. Figure 3-4 shows that the data fall well within a 95% confidence, two-sided tolerance bound for a 90% portion of the underlying population.

2. The data points fall relatively near the regression line and no statistical anomalies are indicated, i.e., the data are visually remote from the prediction and tolerance bounds. It is noted that three of the four data

points fall below the regression line, however, this is not of statistical significance.

In summary, the visual examination doesn't indicate any significant departures from the reference database.

Since the burst pressure data from the South Texas Unit-2 tube specimens were not indicated to be from a separate population from the reference data, the regression analysis of the burst pressure on the common logarithm of the bobbin amplitude was repeated with the additional data included. A comparison of the regression results obtained by including these data in the regression analysis is provided in Table 3-7. Regression predictions obtained by including these data in the regression analysis are also shown on Figure 3-5. A summary of the changes is as follows:

1) The intercept of the burst pressure, P_B, as a linear function of the common logarithm of the bobbin amplitude regression line is decreased by 0.3%, or about 25 psi. Because of the logarithmic scale, the intercept corresponds to a bobbin amplitude of 1 V. The change has the effect of uniformly decreasing the predicted burst pressure as a function of the bobbin amplitude by a minuscule amount.

2) The absolute slope of the regression line is increased by 0.1%, i.e., the slope is more steep. This has the effect of decreasing, albeit very slightly, the burst pressure as a function of bobbin amplitude for large indications, i.e., for those indications with a log-amplitude greater than the mean log-amplitude (about 2.5 V).

3) There is no meaningful change in the standard error of the residuals.

The net effect of the changes on the SLB structural limit, using 95%/95% lower tolerance limit material properties, is to decrease it by 0.09 V, i.e., from 4.79 to 4.70 V. For a SLB differential pressure of 2405 psi, the structural limit decreases from 5.80 to 5.69 V. This results from the increase in the slope coupled with no meaningful change in the intercept and standard error. When coupled with the fact that the structural limit is decreased indicates that the probability of burst (PoB) would decrease for bobbin indications with amplitudes less than about 1 V (the logarithm is zero and it is near the centroid of the logarithm of the volts), would increase for indications greater than about 1 V up to the upper bound of the structural range of interest. Based on the relatively small change in the structural limit, the change in the PoB would also be expected to be small. The effects of the changes on the PoB are illustrated on Figure 3-6. As expected the PoB is decreased up to about 1 V and increases slightly for indications with larger amplitudes.

3.3.2 Probability of Leak Correlation

The data of Table 3-6 were examined relative to the reference correlation for the probability of leak (PoL) as a function of the common logarithm of the bobbin amplitude. Figure 3-7 illustrates the South Texas Unit-2 data relative to the reference correlation. One of the specimens exhibited expected PoL behavior, i.e., the indication had a calculated low probability of leak and did not leak. The other two indications had estimated probabilities of leak of about 0.2 and 0.6. Both of these indications leaked at the SLB differential pressure. These results are not statistically different from the expectation. Had the test results been significantly different from the expectation, statistically anomalous behavior might have been suspected. Thus, based on the data examination, there is no significant evidence of irregular results, i.e., outlying behavior is not indicated.

In order to assess the quantitative effect of the new data on the correlation curve, the database was expanded to include the South Texas Unit-2 data points and a *Generalized Linear Model* regression of the PoL on the common logarithm of the bobbin amplitude was repeated. A comparison of the correlation parameters with those for the reference database is shown in Table 3-8. These results indicate:

1) A 8.0% increase (smaller absolute of a negative value) in the *logistic* intercept parameter.

2) A 4.3% decrease in the *logistic* slope parameter.

3) The absolute values of the variance and covariance of the parameters changed by 15% to 22%. Examination of Figure 3-7 indicates that it is likely that the probability of leak of all indications in the range of interest is increased by the inclusion of the South Texas Unit-2 data. However, the PoL equation generally has a small effect on the total estimated leak rate and it would be expected that there would be no significant impact on the 95% confidence bound on the total estimated leak rate from a single SG.

4) The deviance of the regression increased by 9.8%. An increase is expected when additional data is added. The Pearson standard error decreased by almost 14%, i.e., from 1.12 to 0.97, indicating an improvement in the models predictions.

In order to examine the changes to the PoL, the reference correlation and the new correlation were also plotted on Figure 3-7. An examination of the figure indicates an increase in the PoL on the order of a few percent for all indications over about 1 volt. It is noted that when the total leak rate is determined using the leak rate to bobbin volts correlation, the resulting value can be quite insensitive to the form of the PoL function. So, the effect of the changes in the parameter values and variances would be expected to be small relative to the calculation of the 95% confidence bound of the total leak rate from a SG.

3.3.3 SLB Leak Rate Versus Bobbin Amplitude Correlation

As previously noted, two of the removed tube specimens exhibited leakage under SLB conditions. The leak rates, described earlier in Section 3.1, are depicted on Figure 3-8 relative to the correlation obtained using the reference database. The two data points from South Texas Unit-2 exceed the reference correlation curve for the median leak rate. It is implied from the visual examination, using the relative distance from the 95% confidence bound on the arithmetic average to the arithmetic average, that the data would fall well within a 90% non-simultaneous, two-sided prediction band. Thus, the visual appearance of the data indicates strong support for the trend of the prior correlation. A summary of the parameters of the correlations is provided in Table 3-9. The following changes resulted from the addition of the new data:

1) The intercept of the correlation curve increased (smaller absolute of a negative value) by 14%.

2) The slope of the correlation curve decreased by 7.6%.

3) The standard deviation of the common logarithm of the leak rate residual errors increased by 2.5%.

4) The *p* value for the slope coefficient increased by a factor of 2.7 to $2 \cdot 10^{-11}$. This change is of no statistical significance.

The net effect of including the additional data is to slightly increase the expected, i.e., arithmetic average, leak rate for bobbin amplitudes over most of the range of the data. In practice, the change to the estimated leak rates would be expected to be not significant relative to allowable values.

It is important to note that the pressurizer power operated relief valves (PORVs) at South Texas Unit-2 may be considered to be available and operable during a postulated SLB event. Therefore, the predicted leak rates at a differential pressure of 2405 psi (based on a PORV set-point of 2335 psi plus 3% for accumulation) are applicable for the calculation of total leak rates. The parameters of the regression fit of the leak rate data for a differential pressure of

2405 psi are listed in Table 3-10, and the correlation of the leak rate to the logarithm of the bobbin amplitude is illustrated on Figure 3-9.

3.3.4 Conclusions Relative to ODSCC Correlations

The review of the effect of the South Texas Unit-2 data indicates that the correlations of the burst pressure, the probability of leak, and the leak rate to the common logarithm of the bobbin amplitude would not be substantially changed by the inclusion of the data. Although, both the PoL and expected leak rates would increase, the effect on total predicted leak rates can be expected to be relatively small. It is judged to be likely that the conclusions relative to EOC probability of burst and EOC total leak rate based on the use of the reference database would not be significantly changed relative to results obtained from correlations developed after adding the South Texas Unit-2 data to the database.

Table 3-1. Summary of NDE Data on South Texas Unit 2 S/G Tubes

Location	Field Eddy Current		Field Data Review		Lab Eddy Current	
	Bobbin Coil	0.080" Pancake (600 kHz)	Bobbin Coil	+Point (300 kHz)	Bobbin Coil	+Point (300 kHz)
	volts/%TW	volts/%TW	volts/%TW	volts/%TW/ length (")	volts/%TW	volts/%TW/ length (")
R18C100, TSP-1	NDD	NDD	NDD	NDD	NDD	NDD
R18C100, TSP-2	1.25/PI	0.56/SAI	1.21/PI	0.66/<20/0.5	1.1/PI	.28/72/0.69
R18C100, TSP-3	4.03/PI	3.72/SAI	4.08/83	2.2/81/0.50	5.2/75	2.5/93/0.7 0.13/<20/.2
R18C100, TSP-4	NDD	NDD	NDD	NDD	NDD	NDD
R19C83, TSP-1	NDD	NDD	NDD	NDD	NDD	NDD
R19C83, TSP-2	2.76/PI	2.78/SAI	2.77/92	2.02/83/0.45	5.2/82	3.99/95/0.61
R19C83, TSP-3	.24/PI	NDD	.23/70	N/A	NDD	NDD
R19C83, TSP-4	NDD	NDD	NDD	NDD	NDD	NDD

NDD - No Detectable Degradation
DI - Distorted Indication
PI - Possible Indication
SAI - Single Axial Indication
N/A - Not Appropriate

Table 3-2. South Texas Unit 2 Leak Test Data

Specimen	Test Type: Differential Pressure (psi)	Leak Rate (liters/hr & gpm)	Test Conditions			
			P_p (psig)	P_s (psig)	T_p (°F)	T_s (°F)
R18C100 TSP-3	NOC: 1344	0.033/0.000145	2330	986	618	618
	ITC: 1917	0.585/0.00258	2438	521	598	612
	SLB1: 2512	7.50/0.0330	2720	208	587	520
R19C83 TSP-2	NOC: 1325	0.180/0.000792	2277	952	604	612
	ITC: 1974	0.248/0.00109	2502	528	596	607
	SLB1*: 2527	4.20/0.0185	2734	207	580	479
	SLB2*: 2581	3.70/0.0163	2789	208	576	544

NOC = normal operating conditions; ITC = intermediate test conditions; SLB = steam line break.

* The leak rate for the SLB1 test of Tube R19C83 TSP-2 was observed to decrease during the second half of the test. This test was terminated and test SLB2 was then run at similar conditions. The leak rate was 13% lower than for the SLB1 test, even though the differential pressure was slightly higher. Differing leak rates for the same test conditions occur relatively infrequently and usually for low to moderate leak rates (tighter cracks); but when differing rates happen, they occur such that lower leak rates are experienced with increasing time. This observation is probably related to ID crud particles becoming trapped in the crack and partially sealing the leak. This hypothesis is supported further by previous test observations where instances of jarring the specimen caused a restoration of higher leak rates. Note that all other leak tests in this series of tests appeared to have a constant leak rate.

Table 3-3. Room Temperature Burst and Tensile Test Data for South Texas Unit 2 S/G Tubes

Location	Burst Pressure, psig	Burst Ductility, %	Burst Length, inches	Burst Width, inches	0.2% Offset Tensile Yield Strength, psi	Tensile Ultimate Strength, psi	Tensile Elongation, %
R18C100, FS	11,000	33.7	1.414	0.321	53,700	101,600	44.2
R18C100, TSP-1	11,100	35.0	1.502	0.319			
R18C100, TSP-2							
Run #1**	6,373	2.5	Mult. Cracks	0.004 Max			
Run #2**	7,196	11.1	0.826	0.225			
R18C100, TSP-3*	5,006	15.0	0.552	0.272			
R18C100, TSP-4	11,000	35.5	1.305	0.379			
R19C83, FS	11,800	34.5	1.630	0.391	57,400	106,300	37.5
R19C83, TSP-2*	5,958	9.7	0.718	0.230			
R19C83, TSP-3	11,700	39.9	1.5772	0.434			

TSP = tube support plate; FS = free span; S/G = steam generator

* Tested with foils, bladders and extensions.

** Initially tested without a foil and bladder. No significant burst opening or tearing at the burst opening tips was observed. As a consequence, the specimen was re-tested using a foil and bladder to obtain a wider burst opening with ductile tears at the crack tips.

*** Burst opening occurred away from TTS location near a Swagelok fitting which reduced the ductility and burst opening dimensions. No corrosion was observed on burst fracture face. The burst near the fitting indicates that no corrosion was present at or near TTS.

Table 3-4. SEM Fractographic Data for OD Intergranular Macrocracks on S. Texas Unit 2 Tubes

Specimen, Location	Length vs. Depth* & Ligament Location (inches/% throughwall)	Positional and Ductile Ligament Data (Area = inches^2 x 10^{-4}; Orientation of Ligament Minor Axis relative to Macrocrack Major Axis in degrees; Orientation of Ligament Major Axis relative to Tube Radius in degrees**)
R18C100, TSP-2, burst fracture at 180°	0.000/00	Macrocrack bottom 0.049" above TSP bottom @ 180°
	0.0485/49	
	0.097/41 ← Ligament 1	Ligament 1: Area = 3.4; Minor Axis @ 90°; Major Axis @ 0°
	0.1455/70	
	0.194/78	
	0.2425/81 ← Ligament 2	Ligament 2: Area = 1.3; Minor Axis @ 90°; Major Axis @ 0°
	0.291/93 ← Ligament 3	Ligament 3: Area = 2.1; Minor Axis @ 90°; Major Axis @ 0°
	0.3395/81 ← Ligament 4	Ligament 4: Area = 1.3; Minor Axis @ 90°; Major Axis @ 0°
	0.388/70	
	0.4365/55	
	0.485/49	
	0.5335/14	
	0.582/29	
	(0.621/00)	Macrocrack top located 0.670" above TSP bottom @180°
	(Macrocrack LAD* = 55%, Maximum Depth = 93%, Macrocrack length = 0.621")	

* Average depths may be calculated by a number of different methods depending upon the need. Methods used are LAD = linear average depth; ATD = average throughwall depth (length weighted average depth); PDA = percent degraded area (relative to cross sectional area of an nondegraded tube).

** Note that the ductile ligaments in the table are described by both a major and a minor axis orientation. The ligaments are usually considerably deeper/longer (major axis) than wide (minor axis). The ligament major axis is that going from the OD to the ID of the tube wall (or from the ID to the OD in the case of ID origin cracks) and is usually close in orientation to the radius of the tube. The orientation of the major axis is relative to the tube radius. The minor axis of the ligament is the observed orientation where the ligament jumps from one microcrack to another microcrack as viewed from the OD. The orientation of the minor axis is relative to the tubing major axis. Usually the minor axis is close to perpendicular to the tube major axis.

Table 3-4 (Continued). SEM Fractographic Data for OD Intergranular Macrocracks on S. Texas Unit 2 Tubes

Specimen, Location	Length vs. Depth* & Ligament Location (inches/% throughwall)	Positional and Ductile Ligament Data (Area = inches^2 x 10^{-4}; Orientation of Ligament Minor Axis relative to Macrocrack Major Axis in degrees; Orientation of Ligament Major Axis relative to Tube Radius in degrees**)
R18C100, TSP-3, left-hand macrocrack of "H" shaped burst opening, overall-burst fracture centered at 310°	0.00/00 0.025/41 0.05/39 0.075/55 0.10/64 0.125/68 0.15/76 0.175/73 0.20/88 (0.21/98) ← Ligament 1 0.225/98← ID Lip #1: 98% TW for 0.04" 0.25/100 ← Ligament 2 0.275/100← Max Depth =100% for 0.045" (0.295/100) 0.30/98← ID Lip #2: 98% TW for 0.095" 0.325/98 0.35/98 ← Ligament 3 (0.390/98) 0.40/82 0.425/77 0.45/73 ← Ligament 4 0.475/64 ← Ligament 5 0.50/60 0.525/49 0.55/49 0.575/38 ← Ligament 6 0.60/46 0.625/32← Ligament 7 (0.637/00) **(Macrocrack LAD* 68%, Maximum Depth = 100% over 0.045", 98% deep over another 0.135", Macrocrack length 0.637")**	Macrocrack top located 0.735" above TSP bottom @ 295° Ligament 1: Area = 0.8; Minor Axis @ 90°; Major Axis @ 0° Ligament 2: Area = 1.3; Minor Axis @ 90°; Major Axis @ 0° Ligament 3: Area = 0.6; Minor Axis @ 90°; Major Axis @ 10° Ligament 4: Area = 4.8; Minor Axis @ 90°; Major Axis @ 0° Ligament 5: Area = 0.4; Minor Axis @ 90°; Major Axis @ 0° Ligament 6: Area = 0.9; Minor Axis @ 90°; Major Axis @ 0° Ligament 7: Area = 0.4; Minor Axis @ 90°; Major Axis @ 0° Macrocrack bottom located 0.098" above TSP bottom @ 295°

Table 3-4 (Continued). SEM Fractographic Data for OD Intergranular Macrocracks on S. Texas Unit 2 Tubes

Specimen, Location	Length vs. Depth* & Ligament Location (inches/% throughwall)	Positional and Ductile Ligament Data (Area = inches² x 10^{-4}; Orientation of Ligament Minor Axis relative to Macrocrack Major Axis in degrees; Orientation of Ligament Major Axis relative to Tube Radius in degrees**)
R18C100, TSP-3, right-hand macrocrack of "H" shaped burst opening, overall-burst fracture centered near 310°	0.00/00 0.025/31 0.05/60 0.075/62 0.10/78 1.125/81 (0.138/97) ← Ligament 1 0.150/97 (0.170/100) 0.175/100 0.20/100 0.225/100 0.250/100 0.275/100 0.300/100 0.325/100 0.350/ND 0.375/ND (≥0.38/ND) **(LAD* over top 0.325" = 79%, Maximum Depth = 100% over ≥ 0.155", 97% deep over another 0.032", Macrocrack length ≥ 0.38")**	Macrocrack top located 0.601" above TSP bottom @ 325° Ligament 1: Area = 1.6; Minor Axis @ 90°; Major Axis @ 10° ND = no data, mechanical damage prevented a depth determination Macrocrack bottom located ≥ 0.221" above TSP bottom @ 325°, based on burst macrophotographs

Table 3-4 (Continued). SEM Fractographic Data for OD Intergranular Macrocracks on S. Texas Unit 2 Tubes

Specimen, Location	Length vs. Depth* & Ligament Location (inches/% throughwall)	Positional and Ductile Ligament Data (Area = inches^2 x 10^{-4}; Orientation of Ligament Minor Axis relative to Macrocrack Major Axis in degrees; Orientation of Ligament Major Axis relative to Tube Radius in degrees**)
R19C83, TSP-2, burst fracture at 250°	0.00/00 0.0455/49 (0.090/61) ← Ligament 1 0.091/100 0.1365/100 0.182/100 0.2275/100 0.273/100 ← Ligament 2 (0.3048/100) 0.3185/92 0.364/72 0.4095/56 (0.436/00) **(Macrocrack LAD* = 77%, Maximum Depth = 100% over 0.2138", Macrocrack length = 0.436")**	Macrocrack bottom located 0.151" above TSP bottom @ 250° Ligament 1: Area = 2.8; Minor Axis @ 90°; Major Axis @ 20° Ligament 2: Area = 1.7; Minor Axis @ 90°; Major Axis @ 0° Macrocrack top located 0.587" above TSP bottom @ 250°

Table 3-5. Summary of South Texas-1 1998 Pulled Tube Eddy Current Results								
Tube	TSP	**Field Call**		Lab. Reevaluation of Field Data			**Post Pull Data**	
		Bobbin Volts[1]	**80 mil Pancake Volts**	**Bobbin Volts[1]**	**Depth**	**+Point Volts**	**Bobbin Volts**	**+Point Volts**
R18C100	1 FDB	NDD	NDD	NDD		NDD		NDD
	2	1.25	0.56 SAI	1.21	PI	0.66 SAI	1.10	0.28 SAI
	3	4.03	3.722 SAI	4.08	83%	2.20 SAI	5.20	2.50 0.13 MAI
	4	NDD	NDD	NDD		NDD	NDD	NDD
R19C83	1 FDB	NDD	NDD	NDD		NDD	NDD	NDD
	2	2.76	2.78 SAI	2.77	92%	2.02 SAI	5.20	3.99 SAI
	3	0.24	NDD	0.23	30%	N/A	NDD	NDD

Notes:

1. Field and laboratory data include cross calibration of ASME standard to the reference laboratory standard.

Table 3-6. South Texas-2 1998 Pulled Tube Data for ARC Applications															
Tube	TSP (1)	Bobbin Data		+Point Volts	Destructive Examination Results				Leak Rate-/hr		Burst Pressure Data - ksi				Use in Corr. Note 4
		Volts	Depth		Max. Depth	Avg. Depth	Crack Length inch	No. Lig.(2)	N. O. 1300 psid	SLB 2405 psid	Meas. Burst Press.	σ_y	σ_u	Adj.(3) Burst Press.	
R18C100	FDB	NDD		NDD	0%						11.100			10.231	None
	2	1.21	PI	0.66	93%	55%	0.621 ≥90% deep for ≈ 0.03"	4	0.0(8)	0.0(8)	7.196			6.632	B, POL
	3	4.08	83%	2.20	100% 100%	Notes 6, 7 68%	≈0.38(6,7) >0.155 TW 0.637 0.045 TW 0.135@98%	1 7	0.0265	3.26 7.24(5)	5.006			4.614	B, L, POL
	4	NDD		NDD	≈ 10%	Not destructively examined					11.000			10.139	None
	FS										11.000	53.7	101.6	10.139	
R19C83	FDB	NDD		NDD											None
	2	2.77	92%	2.02	100%	77%	0.436 0.214 TW	2	0.147	1.59 3.68(5)	5.958			5.209	B, L, POL
	3	0.23	30%	N/A	≈ 10%	Not destructively examined					11.700			10.231	None
	FS										11.800	57.4	106.3	10.318	

Notes:
1. FS is freespan section of tubing with no tube degradation to obtain tensile properties and undegraded tubing burst pressure.
2. Number of uncorroded ligaments with > 50% of ligament length remaining in burst crack face.
3. Burst pressures adjusted to 71.57 ksi, average flow stress at 650° F for 3/4" diameter tubes.
4. B = data to be used in burst correlation, POL = data to be used in probability of leakage correlation, L = data to be used in leak rate correlation.
5. SLB leak rate at 2560 psid.
6. Mechanical damage to specimen prevented fractography and depth measurements over full length of the crack.
7. Burst opening had complex H shape formed from two closely spaced cracks that joined by tearing of the corroded region (≈ 0.1") between the two cracks.
8. Judged to be a non-leaker based on short length between 90% and 93% depth with uncorroded ligaments remaining in the deep section. This indication would not be expected to tear throughwall under SLB conditions.

Table 3-7: Effect of South Texas Unit-2 Data on the Burst Pressure vs. Bobbin Amplitude Correlation

$$P_B = a_0 + a_1 \log(Volts)$$

Parameter	Addendum 2 Database	Database with South Texas 2	New / Old Ratio
a_0	7.42817	7.40278	0.997
a_1	-2.91207	-2.91382	1.001
r^2	82.27%	81.88%	0.995
σ_{Error}	0.86118	0.86077	1.000
Mean log(V)	0.408302	0.407375	0.998
SS log(V)	36.91777	37.06576	1.004
N (data pairs)	93	96	[redacted]
Str. Limit (2560 psi)	4.79 V	4.70 V	0.981
Str. Lomit (2405 psi)	5.80 V	5.69 V	0.981
p Value for a_2	$3.0 \cdot 10^{-36}$	$6.2 \cdot 10^{-37}$	0.210
Reference σ_f	71.565 ksi	[redacted]	[redacted]

Table 3-8: Effect of South Texas 2 Data on the Probability of Leak Correlation

$$\Pr(Leak) = \frac{1}{1 + e^{-[b_1 + b_2 \log(Volts)]}}$$

Parameter	Addendum 2 Database	Database with South Texas 2	New / Old Ratio
b_1	-5.2246	-4.8082	0.920
b_2	8.8034	8.4215	0.957
V_{11} (1)	1.4990	1.1712	0.781
V_{12}	-2.1391	-1.7218	0.805
V_{22}	3.4198	2.8917	0.846
Number of Data	120	123	
Deviance	41.75	45.90	
MSE	0.354	0.379	1.071
Pearson SD	1.124	0.970	0.863

Notes: (1) Parameters V_{ij} are elements of the covariance matrix of the coefficients, b_i, of the regression equation.

Table 3-9: Effect of South Texas 2 Data on the Leak Rate vs. Bobbin Amplitude Correlation (2560 psi)

$$= 10^{[b_3 + b_4 \log(Volts)]}$$

Parameter	Addendum 2 Database	Database with South Texas 2	New / Old Ratio
b_3	-1.90061	-1.63838	0.862
b_4	3.18325	2.94093	0.924
r^2	64.8%	61.6%	0.951
σ_{Error} (b_5)	0.59132	0.60638	1.025
Mean log(V)	0.938156	0.921007	
SS log(V)	2.795994	3.134826	
N (data pairs)	46	48	
p Value for b_2	$7.7 \cdot 10^{-12}$	$2.1 \cdot 10^{-11}$	2.65

Table 3-10: Effect of South Texas 2 Data on the Leak Rate vs. Bobbin Amplitude Correlation (2405 psi)

$$= 10^{[b_3 + b_4 \log(Volts)]}$$

Parameter	Addendum 2 Database	Database with South Texas 2	New / Old Ratio
b_3	-2.087379	-1.870836	0.896
b_4	3.176887	2.976689	0.937
r^2	64.7%	62.8%	0.971
σ_{Error} (b_5)	0.59169	0.597912	1.011
Mean log(V)	0.938156	0.921007	
SS log(V)	2.795994	3.134826	
N (data pairs)	46	48	
p Value for b_2	$8.3 \cdot 10^{-12}$	$9.6 \cdot 10^{-12}$	1.15

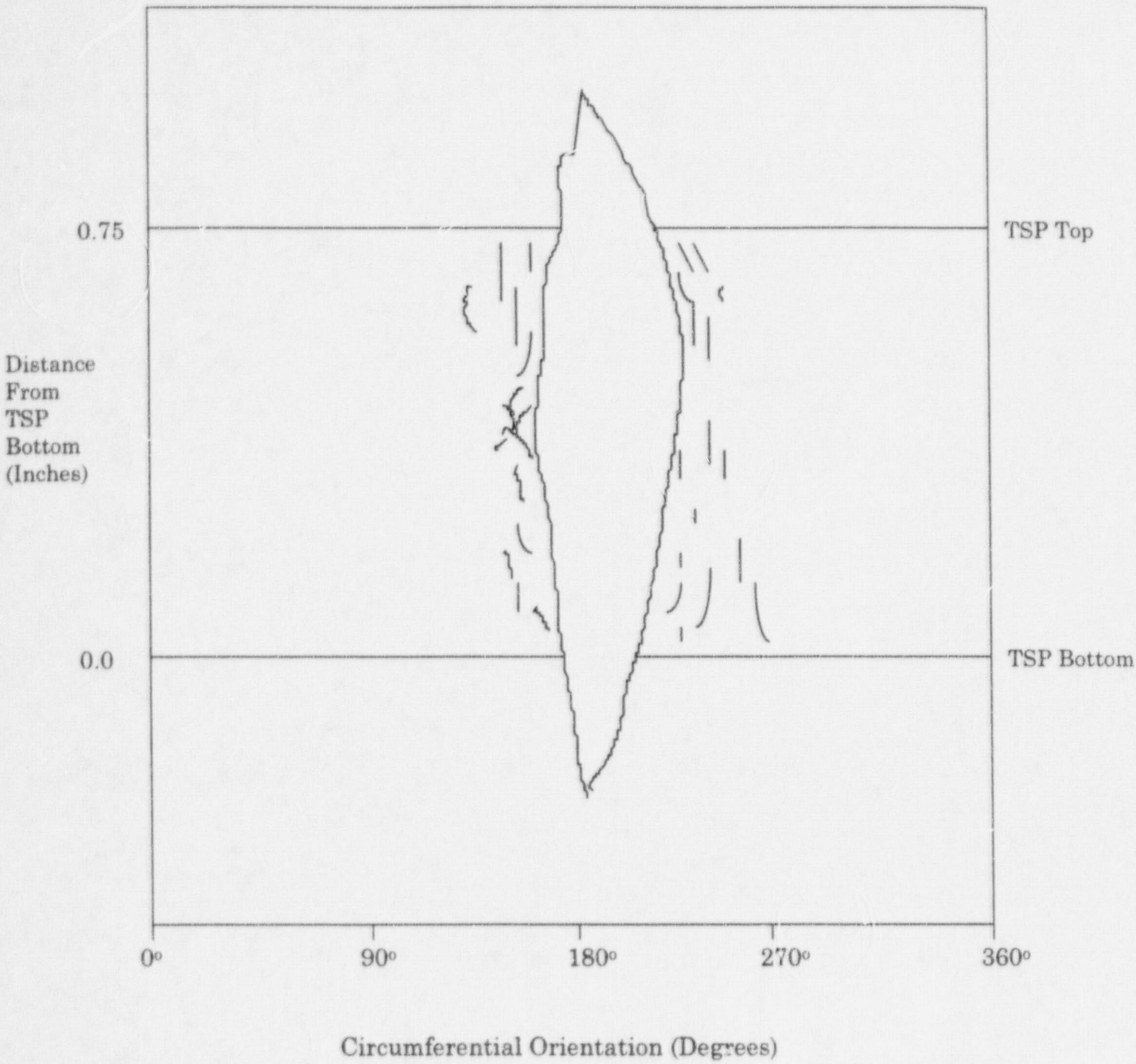


Figure 3-1 Sketch of OD crack distribution observed on the TSP2 region of Tube R18C100. The burst opening also had OD crack features on its fracture face that were confined to the TSP crevice region.

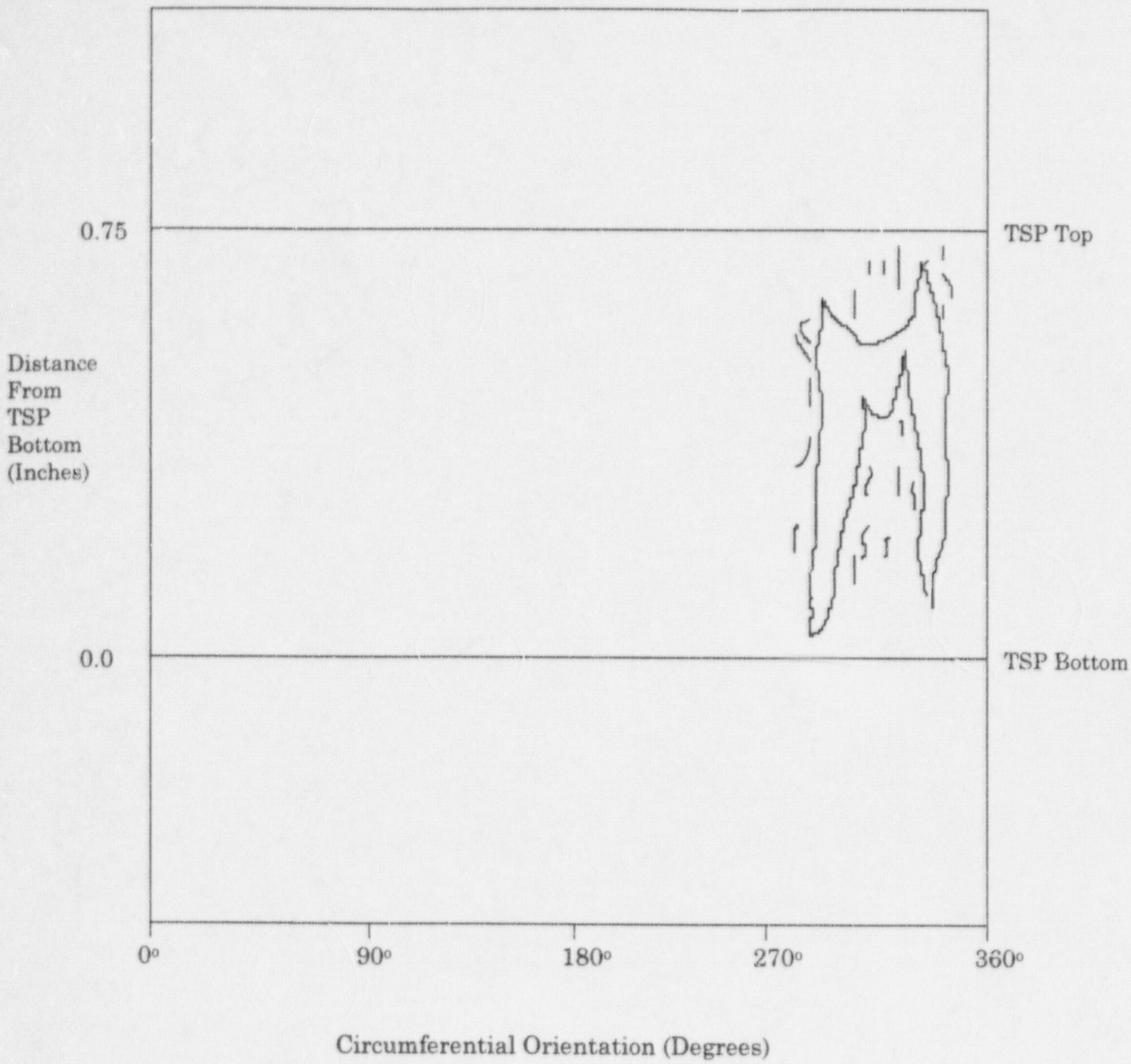


Figure 3-2 Sketch of OD crack distribution observed on the TSP3 region of Tube R18C100. The burst opening also had OD crack features on its fracture face that were confined to the TSP crevice region.

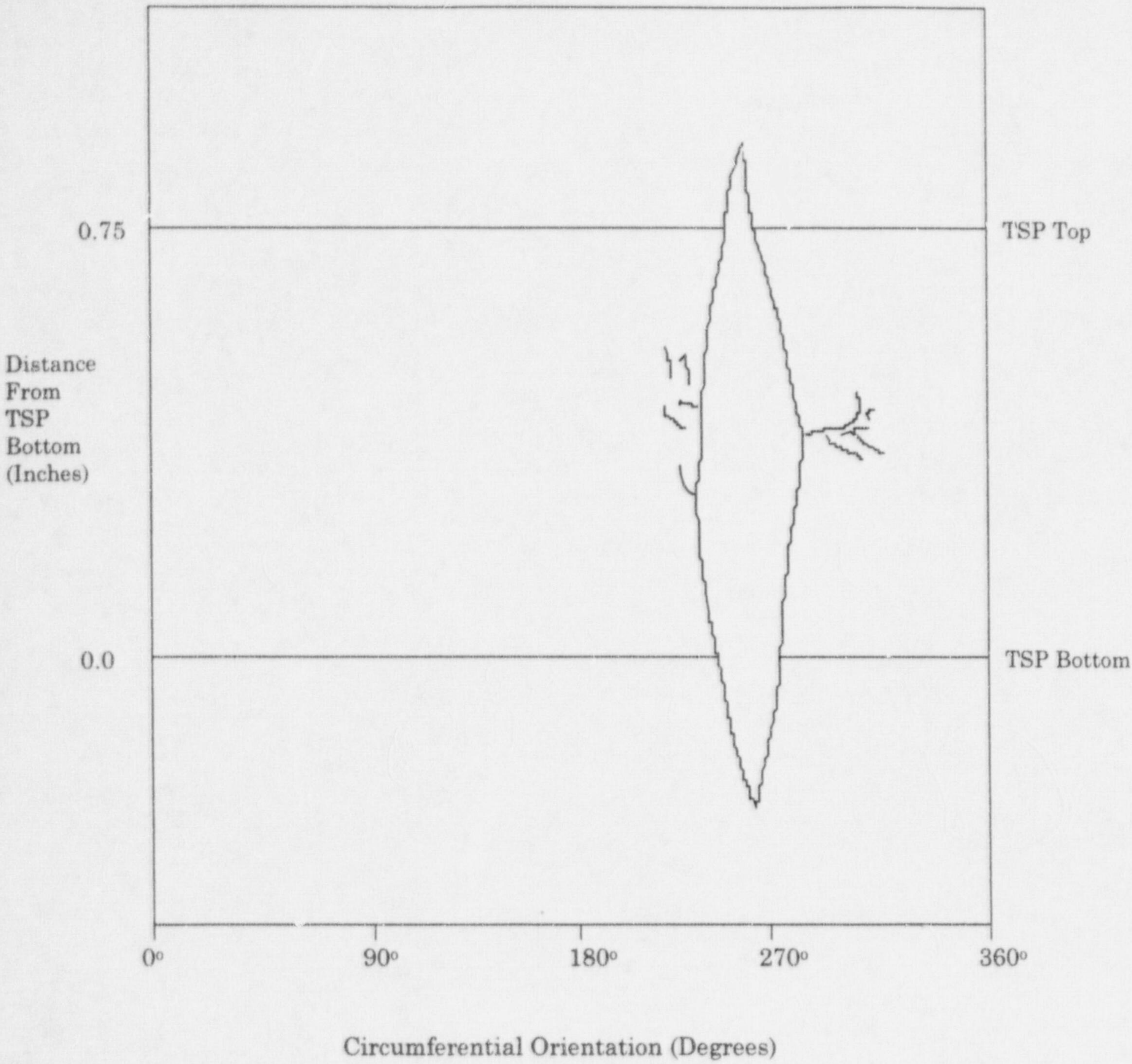


Figure 3-3 Sketch of OD crack distribution observed on the TSP2 region of Tube R19C83. The burst opening also had OD crack features on its fracture face that were confined to the TSP crevice region.

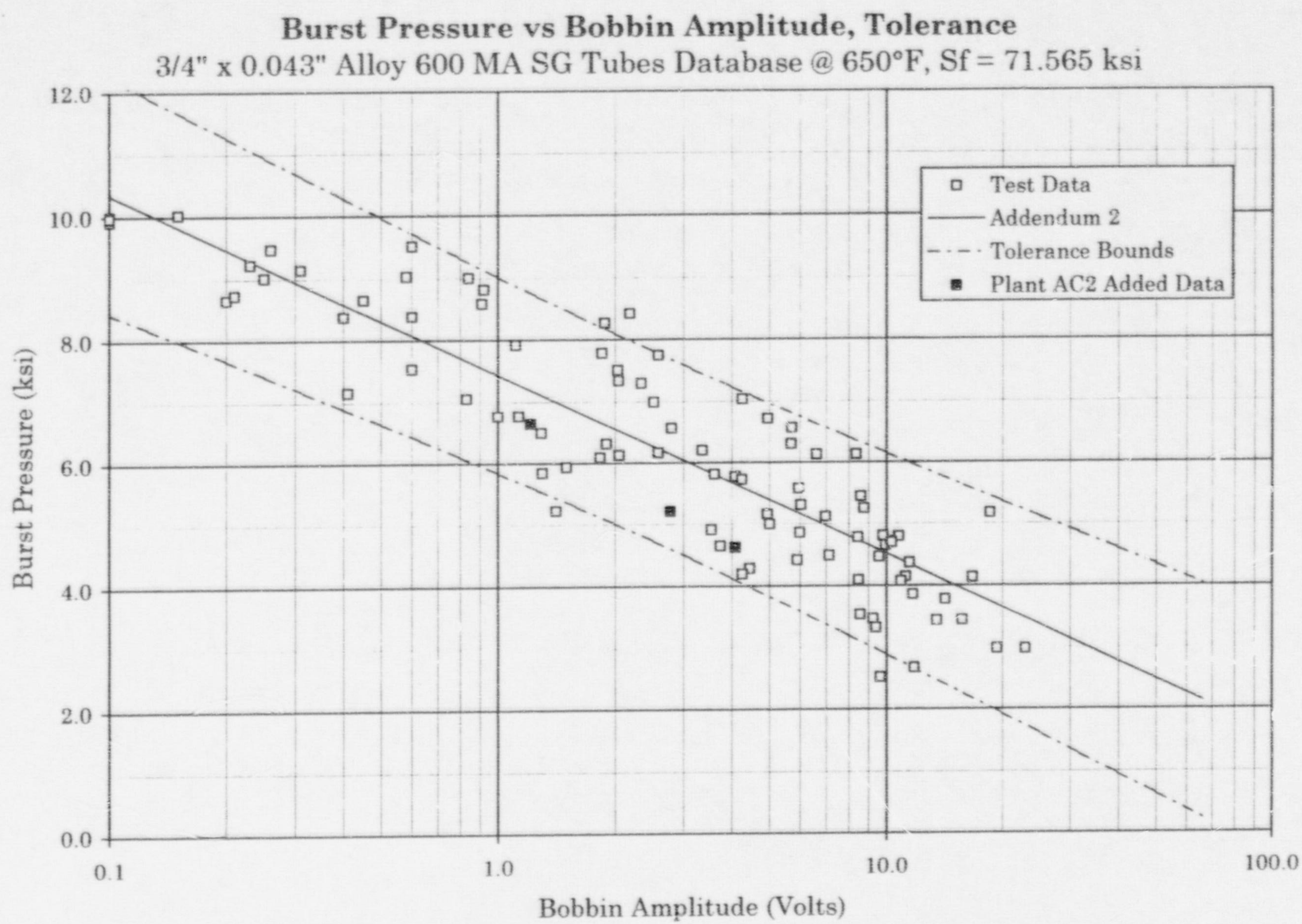

Burst Pressure vs Bobbin Amplitude, Tolerance
3/4" x 0.043" Alloy 600 MA SG Tubes Database @ 650°F, Sf = 71.565 ksi
Test Data
Addendum 2
Tolerance Bounds
Plant AC2 Added Data
Burst Pressure (ksi)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.1
1.0
10.0
100.0
Bobbin Amplitude (Volts)

Figure 3-4

Burst Pressure vs Bobbin Amplitude

3/4" x 0.043" Alloy 600 MA SG Tubes Database @ 650°F, Sf = 71.565 ksi

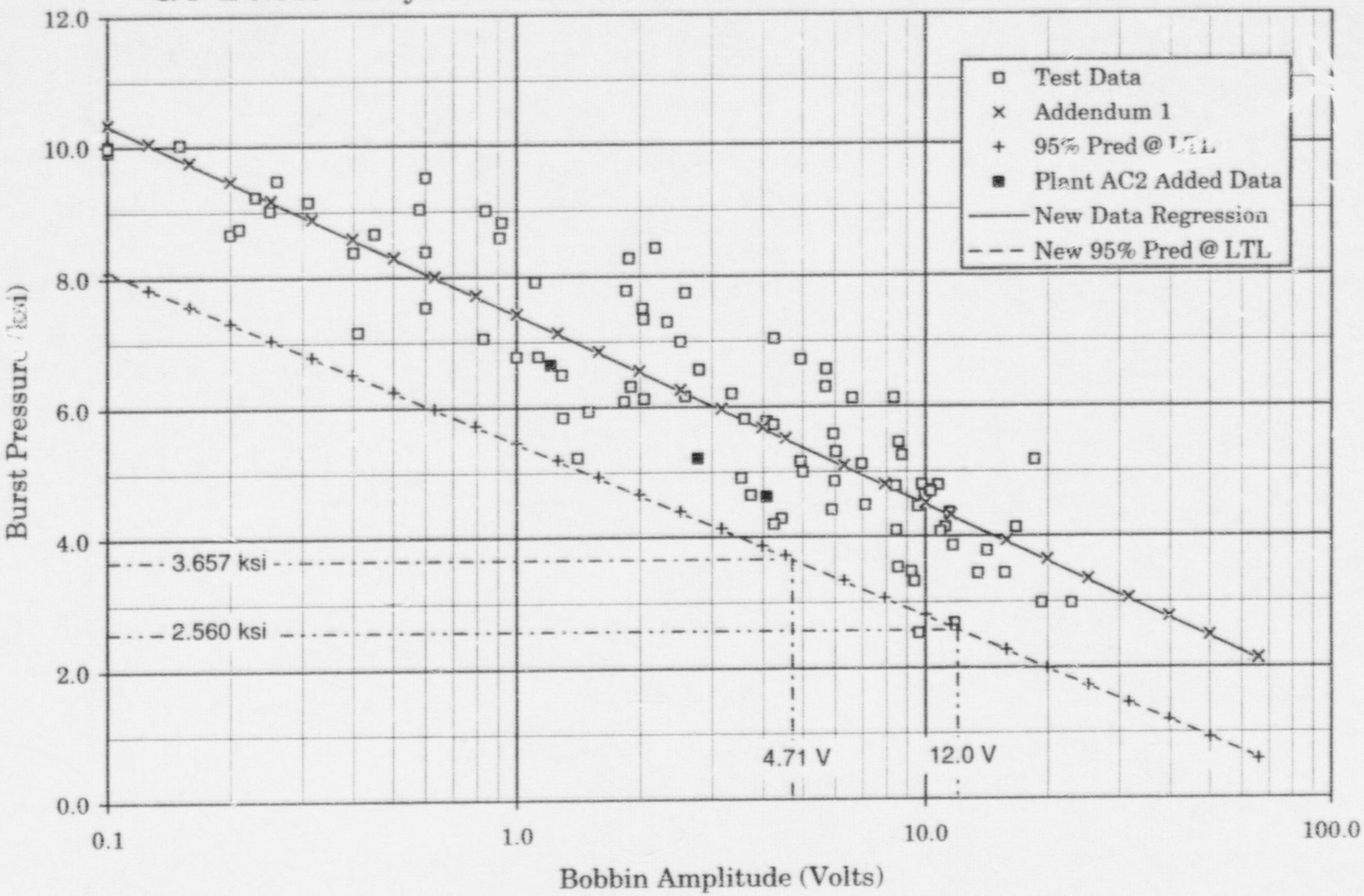


Figure 3-5

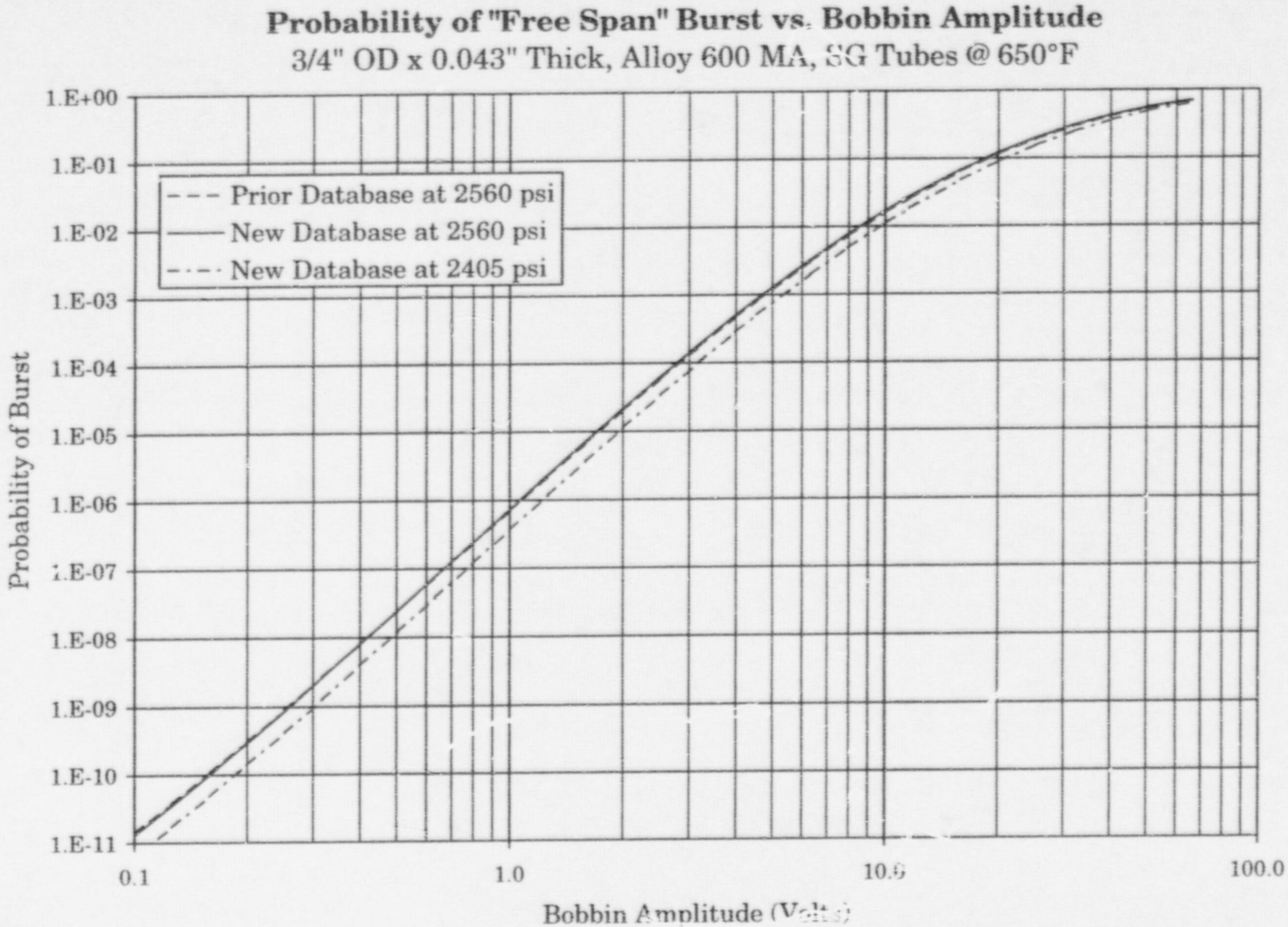

Probability of "Free Span" Burst vs. Bobbin Amplitude
3/4" OD x 0.043" Thick, Alloy 600 MA, SG Tubes @ 650°F
Prior Database at 2560 psi
New Database at 2560 psi
New Database at 2405 psi
Probability of Burst
1.E+00
1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
0.1
1.0
10.0
100.0
Bobbin Amplitude (Volts)

Figure 3-6

Probability of Leak for 3/4" SG Tubes @ 650°F, ΔP = 2560 psi

Comparison of New Data with Addendum 2 Reference Database

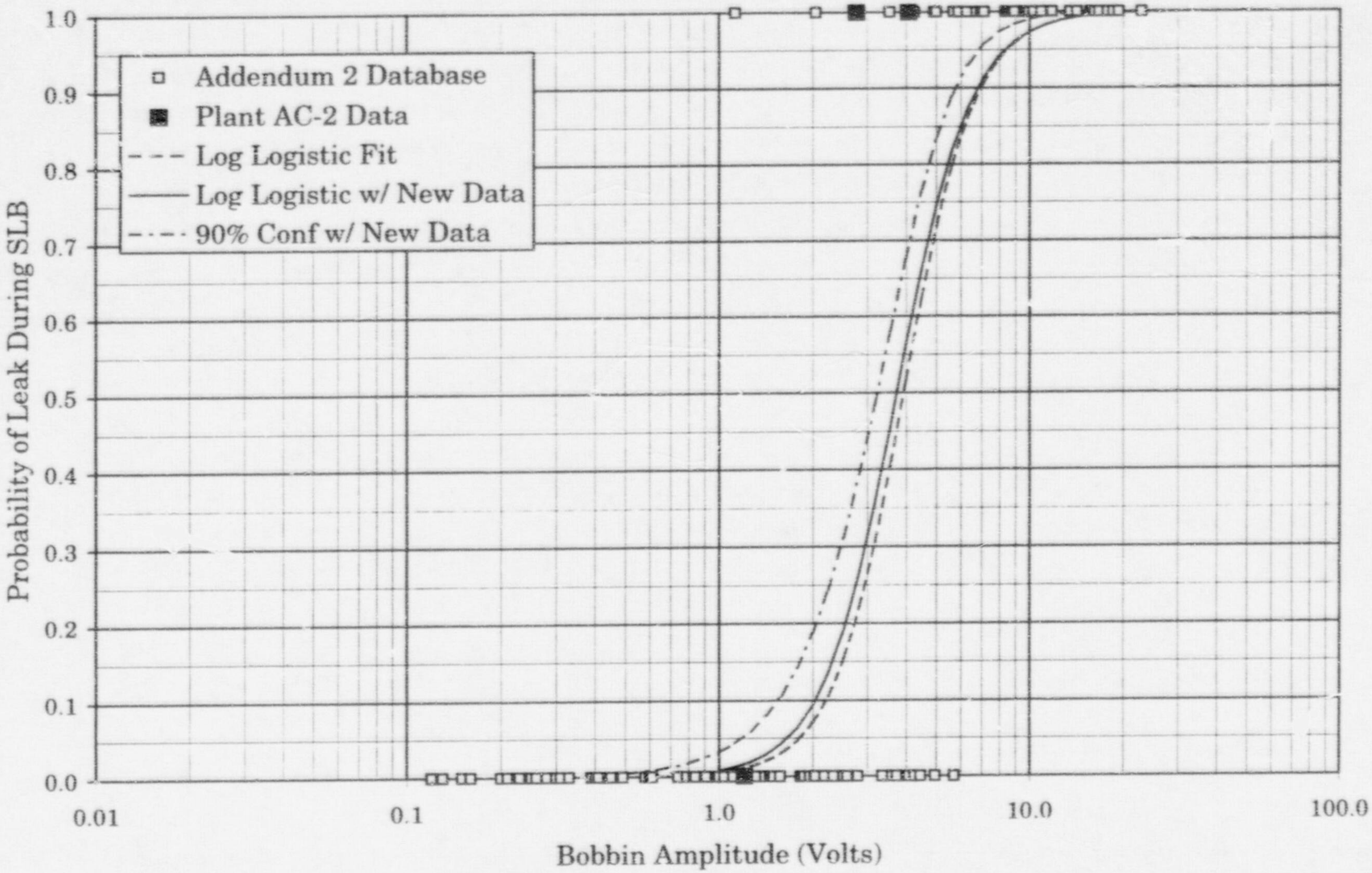
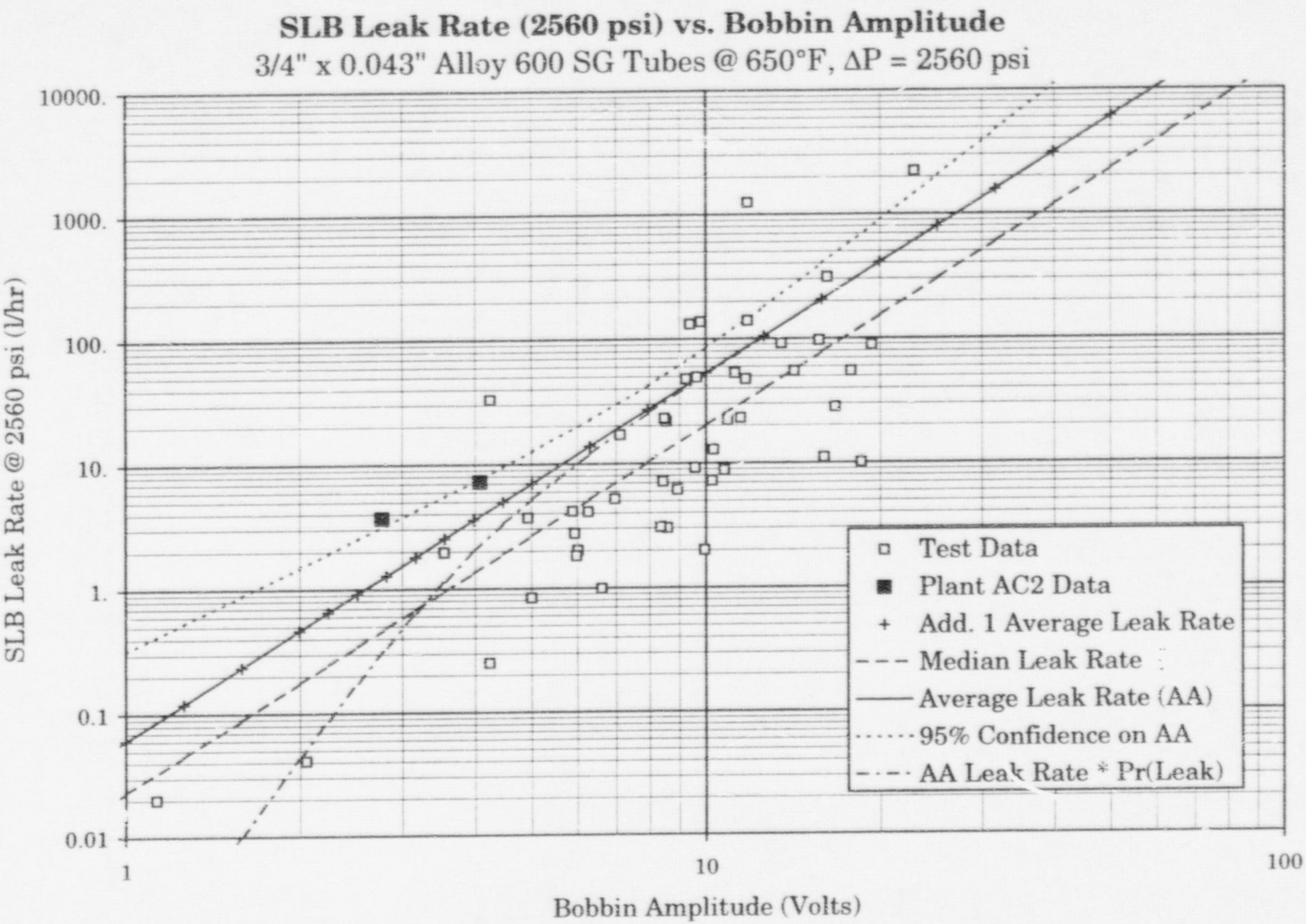


Figure 3-7



SLB Leak Rate (2560 psi) vs. Bobbin Amplitude
3/4" x 0.043" Alloy 600 SG Tubes @ 650°F, ΔP = 2560 psi
10000.
1000.
100.
10.
1.
0.1
0.01
SLB Leak Rate @ 2560 psi (l/hr)
1
10
100
Bobbin Amplitude (Volts)
Test Data
Plant AC2 Data
Add. 1 Average Leak Rate
Median Leak Rate
Average Leak Rate (AA)
95% Confidence on AA
AA Leak Rate * Pr(Leak)

Figure 3-8

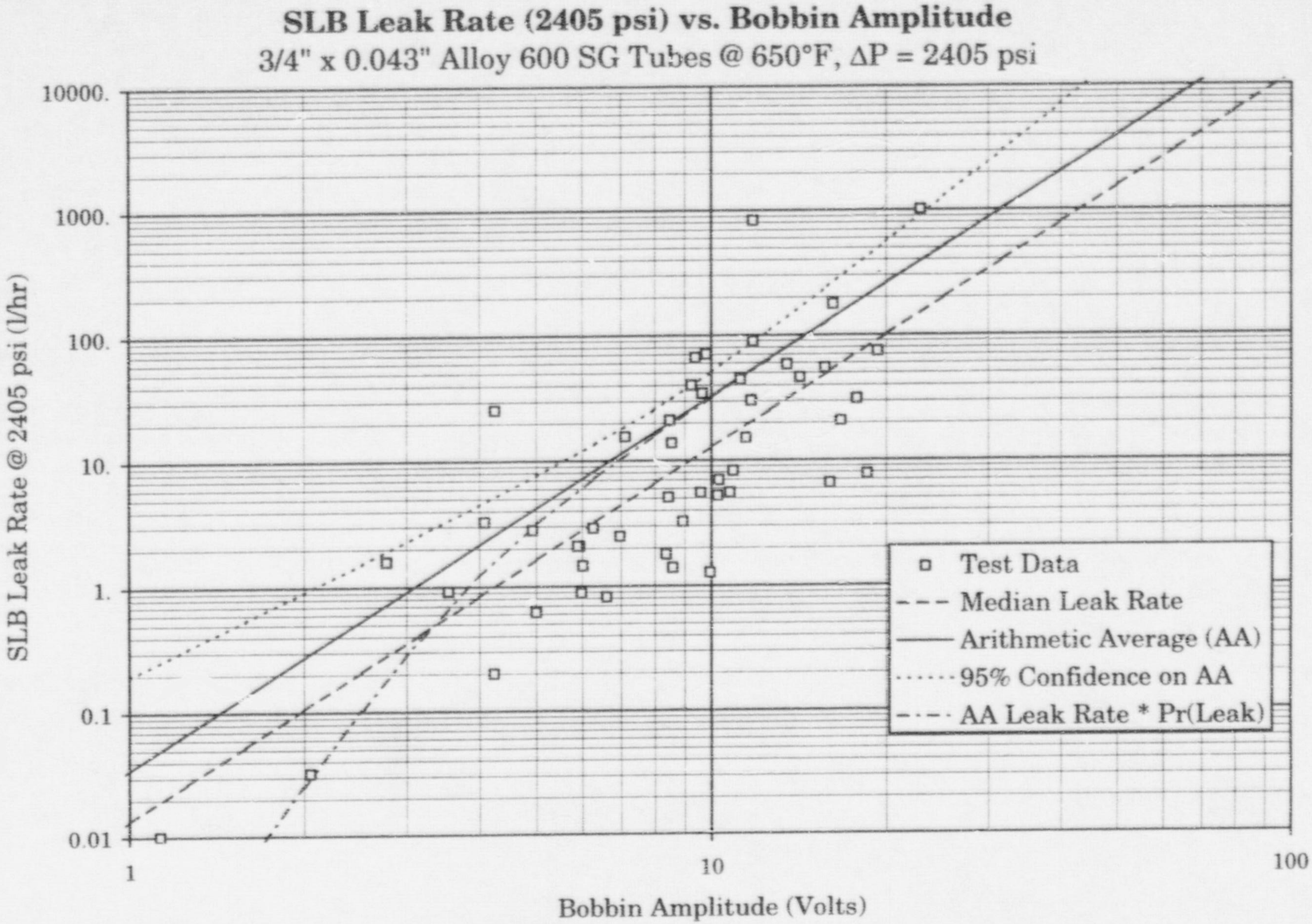

SLB Leak Rate (2405 psi) vs. Bobbin Amplitude
3/4" x 0.043" Alloy 600 SG Tubes @ 650°F, ΔP = 2405 psi
SLB Leak Rate @ 2405 psi (l/hr)
10000.
1000.
100.
10.
1.
0.1
0.01
1
10
100
Bobbin Amplitude (Volts)
Test Data
Median Leak Rate
Arithmetic Average (AA)
95% Confidence on AA
AA Leak Rate * Pr(Leak)

Figure 3-9

4.0 EOC-6 Inspection Results and Voltage Growth Rates

4.1 EOC-6 Inspection Results

According to the guidance provided by the NRC Generic Letter 95-05, the EOC-6 inspection of the South Texas Unit-2 SGs consisted of a complete, 100% eddy current (EC) bobbin probe full length examination of the tube bundles in all four SGs. A 0.610 inch diameter probe was used for all hot and cold leg TSPs where voltage-based repair criterion was applied. RPC examination was performed for all indications on the hot side with amplitude above 1 volt. Thirty-nine indications on the hot leg side had a bobbin voltage above 1 volt. They were all inspected with a RPC probe and 34 were confirmed as flaws and repaired. Only one indication on the cold leg side had a bobbin voltage above 1 volt. This indication was initially called as a wear indication and later reclassified as a potential crack-like indication. It was not RPC inspected but was treated as a RPC-confirmed indication and repaired. This indication is further discussed in the paragraphs below.

Fifteen tubes in SG-D are excluded from voltage-based repair criteria as they are made of thermally treated tubes. As noted in Reference 9-2, tubes in the wedge regions are not excluded from the repair criteria as they are not expected to deform excessively under design-basis SLB conditions.

No RPC circumferential indications at the TSPs, no indications extending outside the TSPs, and no RPC indications with potential ID phase angles were found in this inspection. Also, no signal interference from copper deposits was found. A total of 47 TSP intersections in all 4 SGs with a mixed residual signal (MRI) that could potentially mask a 1.0 volt bobbin indication (MRI voltage 1.5 volts or greater) were inspected with a RPC probe and 4 of them were found to contain single axial indications (SAIs), and they were repaired.

A summary of EC indications for all four SGs is shown on Table 4-1, which tabulates the number of field bobbin indications, the number of those indications that were RPC inspected, the number of RPC confirmed indications, and the number of indications removed from service due to tube repairs. The indications that remain active for Cycle 7 operation is the difference between the observed and the ones removed from service.
Overall, the combined data for all four SGs of South Texas Unit-2 show the following.

- A total of 1485 TSP indications identified during the inspection of which 39 indications on the hot leg side and one indication on the cold side were over 1 volt and 6 of these 39 hot leg indications were over 2 volts.

- All 39 hot leg indications over 1 volt and 5 additional indications under 1 volt were inspected with a RPC probe, 38 were confirmed.

- All 34 RPC-confirmed indications over 1 volt (bobbin) were repaired. In addition 10 more indications were also removed from service because they were present in tubes repaired for non-ODSCC causes. A potential indication on the cold leg side (22C) in tube R1C102 of SG-C with a bobbin voltage above 1 volt was not RPC inspected, but it was treated as a RPC-confirmed indication and repaired. Another cold leg indication with voltage under 1 volt was not repaired. Consistent with the 1 volt repair criteria, indications with bobbin amplitude less than or equal 1.0 volt was not considered for removal from service, regardless of RPC data.

A review of Table 4-1 indicates that SG-C had the highest number of indications returned to service for Cycle 7 operation (498 indications, none above 1.0 volt). However, SG-A had 4 of the 5 indications over 1 volt returned to service (i.e., RPC NDD indications), and it also had larger average growth rate in the last cycle (Cycle 6). Therefore, SG-A may well be the limiting SG at EOC-7 from the standpoint of SLB leak rate and tube burst.

Figure 4-1 shows the actual bobbin voltage distribution determined from the EOC-6 EC inspection; Figure 4-2 shows the population distribution of those EOC-6 indications removed from service due to tube repairs; Figure 4-3 shows the distribution for indications returned to service for Cycle 7. Of the 44 indications removed from service, 34 indications are in tubes repaired because of the TSP voltage-based repair criteria. The rest are in tubes plugged for degradation mechanisms other than ODSCC at TSPs.

The distribution of EOC-6 indications as a function of support plate location is summarized in Table 4-2 and plotted in Figure 4-4. The data show a strong predisposition of ODSCC to occur in the first few hot leg TSPs (1366 out of 1484 or about 92% of the indications occurred at hot leg intersections in the first three TSP above the flow distribution baffle plate), although the mechanism extended to higher TSPs. Only one indication was initially called on the cold leg side (in SG-C). Another bobbin signal at the first pre-heater baffle plate intersection on the cold side (22C) in tube R1C102 in SG-C was initially called as a wear indication and was assigned 2.05 volts. A later reexamination of this bobbin signal indicated that it may be a potential crack-like signal and its voltage was revised to 1.23 volts. As a crack and potential ODSCC indication subject to GL 95-05 requirements, the indication would be required to be RPC inspected. By the time this reassessment was completed, equipment needed for RPC examination of this intersection had been removed from the steam generator. Based on discussions with the NRC, it was concluded that the RPC inspection could be omitted and this tube (R1C102) was repaired, which is equivalent to assuming RPC confirmation of the indication as a crack-like flaw rather than wear. To ensure proper classification of cold leg indications in future inspections, all pre-heater baffle plate intersections on the cold leg side will be inspected with a RPC probe. Both bobbin and RPC data will be used to classify the indications as ODSCC or wear. Indications extending outside these baffle plate intersections will also be RPC inspected. In summary, the distribution of indication population at TSPs in South Texas Unit-2s how predominant temperature dependence of ODSCC, similar to that observed at other plants.

A total of 73 dents with a bobbin voltage over 5 volts were found at TSPs in all 4 SGs combined. (Dents called within ± 0.5" from the TSP center line are considered to be within TSP.) All dented TSP intersections above 5 volts were inspected with a RPC probe in this inspection, and no degradation was found at those locations.

4.2 Voltage Growth Rates

For projection of leak rates and tube burst probabilities at the end of Cycle 7 operation, voltage growth rates were developed from EOC-6 (October 1998) inspection data and a reevaluation of the EOC-5 (May 1997) inspection EC signals for the same indications. Table 4-3 shows the cumulative probability distribution for growth rate in each South Texas Unit-2 steam generator during Cycle 6 (July '97 - October '98) on an EFPY basis, along with the corresponding Cycle 5 growth rate distributions. Cycle 6 growth data are also plotted in Figure 4-5. The curve labelled 'cumulative' in Figure 4-5 represents composite growth data from all four SGs. Cycle 5 growth rates were established using field bobbin data resized per the standard method for bobbin signal evaluation established for plants utilizing voltage-based repair criteria with an exception that history data for new EOC-5 indications under 1 volt were not reevaluated and those indications were not included in the Cycle 5 growth data.

Average growth rates for each SG during Cycle 6 are summarized in Table 4-4. It is evident that the absolute magnitude of average growth in all SGs is relatively small (less than 0.2 volt). Among the four steam generators, SG-D had a larger average voltage growth during Cycle 6, but SG-A had 4 out of the 5 largest voltage growth during Cycle 6 (see Table 4-3). The average growth rates over the entire voltage range vary between 18% and 48.7% (of BOC voltage) per EFPY, between SGs, with an overall average of 27.1% per EFPY. The small average BOC voltages (between 0.25 to 0.44 volt) leads to the relatively large percentage growth even when the average growth ($\leq$ 0.122 volt per EFPY) is very small. The average growth for indications greater than or equal to 0.75 volt is 10.9% per EFPY and for indications less than 0.75 volt it is 28.8% per EFPY. A smaller growth for was concluded that the RPC inspection could be omitted and this tube (R1C102) was repaired, which is equivalent to assuming RPC confirmation of the indication as a crack-like flaw rather than wear. To ensure proper classification of cold leg indications in future inspections, all pre-heater baffle plate intersection indications on the cold leg side will be inspected with an RPC probe. Both bobbin and RPC data will be used to classify the indications as ODSCC or wear. Indications extending outside these baffle plate intersections will also be RPC inspected. In summary, the distribution of indication population at TSPs in South Texas Unit-2s how predominant temperature dependence of ODSCC, similar to that observed at other plants.

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Figure 4-6 is a plot of voltage growth during Cycle 6 vs. BOC-6 voltage. An examination of Figure 4-6 indicates that the Cycle 6 growth data for SG-A seem to show a dependency on BOC-6 voltage since essentially all large growth values (say, over 0.5 volt) occurred at BOC voltages greater than the mean BOC voltage (0.44 volt). However, SG-A also had many indications towards the high end of the BOC voltage spectrum with growth well below 0.5 volt. To examine the impact of the voltage-dependent growth trend observed for SG-A on tube integrity projections, SLB leak rate and tube burst probability projection for the EOC-7 condition for SG-A was carried using the methodology recommended in Reference 9-4 for considering growth dependency on BOC voltage, and the results are discussed in Section 8.0.

Averaged composite voltage growth data from all four steam generators for the last two operating periods are summarized in Table 4-5. The guidelines in Generic Letter 95-05 require the use of more conservative growth rate distributions from the past two inspections for projecting EOC distributions for the next operating cycle. It is evident that the average growth rate/EFPY for Cycles 5 and 6 are comparable, with Cycle 5 having a slightly higher growth. However, as noted before, Cycle 5 growth distribution does not include EOC-5 indications under 1 volt, which could exclude low growth indications and its average growth may be overestimated. Furthermore, Cycle 6 data includes 3 growth values over 1 volt and a value over 2.1 volts while the growth rates for Cycle 5 are all equal to or less than 1 volt (see Table 4-3 and Figure 4-7 where cumulative probability distribution for the composite growth rate data from all SGs during Cycle 6 is compared with that for Cycle 5). Hence, SLB leak rate and tube burst probability projections for the EOC-7 condition based on the Cycle 6 data would yield more conservative results; therefore, Cycle 6 growth distribution was applied to obtain EOC-7 projections.

From Table 4-3 and Figure 4-5 it is evident that the Cycle 6 growth rates at larger growth values (> 0.3 volt) for SG-A are higher than the composite growth distribution. Also, at lower growth values (below 0.6 volt) Cycle 6 growth rates for SG-D are higher than the composite growth rates. Per the methodology described in Reference 9-3, SG-specific growth rates are to be used for SGs A and D, while the composite growth rates should be applied for SGs B and C. The SG-specific growth data for SG-D do not include any of the top 4 growths observed for Cycle 6. Since a few relatively high growth values observed during each cycle can be expected to occur randomly in any SG, it is not considered highly improbable that highest growth for the ongoing cycle would occur in SG-D. To account for such a possibility, the top 3 growth values for Cycle 6 were added to the SG-specific growth distribution applied to the EOC-7 projection for SG-D.

Table 4-6 lists the top 30 indications on the basis of Cycle 6 growth rates in descending order. Twenty-three of those indications were RPC confirmed and the remaining 7 were either not inspected or no degradation was found (NDFs). All but one of the 30 indications shown are new indications, and the EOC-5 voltages used to estimate growth rates for them were obtained by reevaluating the prior inspection data. The result that the indications are new is to be expected since only RPC NDD indications were left in service at BOC-6 (repair on detection criterion was used at EOC-5).

4.3 NDE Uncertainties

The NDE uncertainties applied for the Cycle 6 voltage distributions in the Monte Carlo analyses for leak rate and burst probabilities are the same as those previously used for the South Texas Unit-1 voltage-based repair criteria report of Reference 9-6 and NRC Generic Letter 95-05 (Reference 9-1). They are presented in Table 4-7 as well as graphically illustrated in Figure 4-8. The probe wear uncertainty has a standard deviation of 7.0 % about a mean of zero and has a cutoff at 15 % based on implementation of the probe wear standard. The analyst variability uncertainty has a standard deviation of 10.3% about a mean of zero with no cutoff. These NDE uncertainty distributions are included in the Monte Carlo analyses for SLB leak rates and tube burst probabilities based on the EOC-6 actual voltage distributions as well as for the EOC-7 projections.

4.4 Probability of Prior Cycle Detection (POPCD)

Although a voltage-based repair criteria is being applied for the first time for South Texas Unit-2, bobbin and RPC data evaluated consistent with the Generic Letter 95-05 guidelines are available for two inspections (EOC-5 and EOC-6 inspections). As part of preparing the technical justification report for 1 volt repair criteria (Reference 9-2), the EOC-5 field bobbin data were reevaluated using a standard procedure developed for plants using voltage-based repair criteria. Therefore, with availability of EOC-6 inspection results, probability of detection at the prior EOC-5 inspection (POPCD) can be evaluated. For voltage-based repair criteria applications, the important indications are those that could significantly contribute to EOC leakage or burst probability. These significant indications can be expected to be detected by bobbin and confirmed by RPC inspection. Thus, the population of interest for voltage-based repair criteria POD assessments is the EOC RPC confirmed indications that were detected or not detected at the prior inspection. The probability of prior cycle detection (POPCD) for the EOC-6 inspection can then be defined as follows.

$$\text{POPCD (EOC-5)} = \frac{\text{EOC-5 cycle reported indications confirmed by RPC in EOC-6 inspection} + \text{Indications confirmed and repaired in EOC-5 inspection}}{\{\text{Numerator}\} + \text{New indications RPC confirmed in EOC-6 inspection}}$$

POPCD is evaluated at the 1997 EOC-5 voltage values (from 1998 reevaluation for growth rate) since it is an EOC-5 POPCD assessment. The indications detected at EOC-5 that were RPC confirmed and plugged are included as it can be expected that these indications would also have been detected and confirmed at EOC-6. It is also appropriate to include the plugged tubes for voltage-based repair criteria applications since POD adjustments to define the BOC distribution are applied prior to reduction of the EOC indication distribution for plugged tubes.

It should be noted that the above POPCD definition includes all new EOC-6 indications not reported in the EOC-5 inspection. The new indications include EOC-5 indications present at detectable levels but not reported, indications present at EOC-5 below detectable levels and indications that initiated during Cycle 6. Thus, this definition, by including newly initiated indications, differs from the traditional POD definition. Since the newly initiated indications are appropriate for voltage-based repair criteria applications, POPCD is an acceptable definition and eliminates the need to adjust the traditional POD for new indications.

The above definition for POPCD would be entirely appropriate if all EOC-5 indications were RPC inspected. Since only a fraction of bobbin indications are generally RPC inspected, POPCD could be distorted by using only the RPC inspected indications. Thus, a more appropriate POPCD estimate can be made by assuming that all bobbin indications not RPC inspected would have been RPC confirmed. This definition is applied only for the 1998 EOC-6 indications not RPC inspected since inclusion for the EOC-5 inspection for repaired tube could increase POPCD by including indications on a tube plugged for non-ODSCC causes which could be RPC NDF indications. In addition, the objective of using RPC confirmation for POPCD is to distinguish detection of indication at EOC_{n-1} that could contribute to burst at EOC_n so that the emphasis is on EOC_n RPC confirmation. This POPCD can be obtained by replacing the EOC-6 RPC confirmed by RPC confirmed plus not RPC inspected in the above definition of POPCD. For this report, both POPCD definitions are evaluated for South Texas Unit-2.

It can be noted that many of the new indications not RPC inspected can be false calls and are not found at the subsequent inspection. It would be appropriate to define new indications as the net increase in new indications at EOC-6 minus indications reported at EOC-5, but not found at EOC-6. This would represent the net new number of unconfirmed indications. Ignoring this effect leads to conservative POPCD distribution.

The POPCD evaluation for the 1997 EOC-5 inspection data is summarized in Table 4-8 and illustrated on Figure 4-9. As seen from Table 4-8, during the EOC-5 inspection a large number of indications under 1 volt were RPC tested and those confirmed were repaired since "plug on detection" criteria was applied then. However, relatively few indications under 1 volt were RPC tested in the EOC-6 since 1.0-volt repair was applicable. Because of this disparity in the RPC inspection of indication under 1 volts, POPCD based on RPC-confirmed only indications is not reliable. Therefore, only the results based on RPC confirmed plus not RPC inspected indications are shown in Figure 4-9. It is evident that South Texas Unit-2 POPCD values support a POD significantly higher than the NRC mandated value of 0.6. A generic POPCD distribution developed by analyses of 18 inspections in 10 plants and presented in Table 7-4 of Reference 9-4 is also shown in Figure 4-9. It is seen from Figure 4-9 that the POPCD values for South Texas Unit-2 are comparable to the generic POPCD in the voltage range 0.2 to 0.6 volt, and between 0.6 to 1.5 volts it is below the generic data. The POPCD value reaches unity at about 1.5 volts.

In summary, the South Texas Unit-2 EOC-6 POPCD supports a POD higher than the NRC mandated POD value of 0.6.

4.5 Assessment of RPC Confirmation Rates

This section tracks the 1997 EOC-5 indications left in service at BOC-6 relative to RPC inspection results in 1998 at EOC-6. If sufficient plant-specific data is available on RPC confirmation rates for prior cycle NDFs, NRC approval may be obtained for considering only a fraction of unconfirmed (RPC NDF) indications in the BOC voltage distributions used for SLB leak rate and tube burst probability projections. The object of this evaluation is to build such a database for later submittal to NRC.

The composite results from this evaluation for all 4 SGs are given in Table 4-9. For 1997 bobbin indications left in service, the indications are tracked relative to 1998 RPC confirmed, 1998 RPC NDF, 1998 bobbin indications not RPC inspected, and 1997 bobbin indications with no indication found in 1998. Also included are new 1998 indications. The table shows, for each category of indications, the number of indications RPC inspected and RPC confirmed in 1998, as well as the percentage of RPC confirmed indications.

Only 4 out of 310 EOC-5 RPC NDF indications in service at BOC-7 were RPC tested during the EOC-6 inspection and 3 were confirmed. Therefore RPC confirmation rate for prior RPC NDF indications is 75%. This RPC NDF database for South Texas Unit-2 is still too small to recommend a confirmation rate for use in the projection analyses. All RPC NDF indications are included in the EOC-7 projections presented in Section 8.0.

4.6 Probe Wear Criteria

An alternate probe wear criteria approved by the NRC (Reference 9-7) was applied during the EOC-6 inspection. When a probe does not pass the 15% wear limit, this alternate criteria requires that only tubes with indications above 75% of the repair limit since the last successful probe wear check be reinspected with a good probe. As the repair limit is 1 volt, all tubes containing indications for which worn probe voltage was above 0.75 volt were inspected with a new probe. An evaluation of worn probe and new probe data is presented in the following paragraphs.

In accordance with the guidance provided in Reference 9-7, voltages measured with a worn probe and a new probe at the same location were analyzed to ensure that the voltages measured with worn probes are within 75% of the new probe voltages. No new indications were detected with new probes; thus, worn probes did not miss any indication. Figures 4-10 and 4-11 show plots of the worn probe voltages plotted against the new probe voltages for all 4 SGs, and the data in these two figures show a consistent relationship between the two voltages. There are 2 indications with a worn probe voltage of about 2 volts for which the new probe voltage is about 17% to 25% higher. Composite data from all 4 SGs are plotted in Figure 4-12. Also shown in Figure 4-12 as a solid line is a linear regression for the data, dashed lines representing tolerance limits that bound 90% of the population at 95% confidence, and chained lines representing ±25% band for the new probe voltages. The mean regression line has slightly less than

45° slope indicating that on the average new probe voltages are slightly higher than the worn probe voltages. The dotted horizontal line at 0.75 worn probe volts demarcates indications requiring retest from those that do not. The shaded area at the bottom above 1 volt shows the region where a tube requiring repair may be left in service because of probe wear. In the South Texas Unit-2 EOC-6 inspection, there are no occurrences for which a worn probe was less than 0.75 volt and the new probe voltage exceeded the plugging limit, i.e., no pluggable tubes were missed due to probe wear considerations.

Among the indications requiring retesting (worn probe volts > 0.75 volt), 4 indications < 0.6 volt with the new probe fall outside the 90%/95% tolerance limit bands and ±25% of the new probe voltage bands. All these 4 indications lie above the upper 90%/95% tolerance band as well as the upper 25% band; i.e., the worn probe voltages are higher than the corresponding new probe voltages and the worn probe voltages are conservative. Therefore, the data for these 4 indications are acceptable. Also, there are 5 indications below the lower 90%/95% tolerance band for which the new probe voltage exceeds the worn probe voltage. However, all these 5 indications are small (<0.75 volt with the new probe) and the new and worn probe voltages differ by only few tenths of a volt; a voltage variation of this magnitude can be expected if the measurement is repeated with new or worn probes. Therefore, the data for 5 indications below the lower 90%/95% tolerance band are acceptable.

Overall, it is concluded that the criteria to retest tubes with worn probe voltages above 75% of the repair limit is adequate. The alternate probe wear criteria used in the EOC-6 inspection is consistent with the NRC guidance provided in Reference 9-7.

Table 4-1 (Sheet 1 of 2)
South Texas Unit 2 October 98 Outage
Summary of Inspection and Repair For Tubes in Service During Cycle 6

	Steam Generator A						Steam Generator B						Steam Generator C					
	In-Service During Cycle 6				RTS for Cycle 7		In-Service During Cycle 6				RTS for Cycle 7		In-Service During Cycle 6				RTS for Cycle 7	
Voltage Bin	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only
0.1	0	0	0	0	0	0	2	0	0	0	2	2	4	0	0	0	4	4
0.2	5	0	0	0	5	5	59	0	0	0	59	59	38	0	0	0	38	38
0.3	40	0	0	1	39	39	125	0	0	0	125	125	96	0	0	1	95	95
0.4	40	0	0	1	39	39	124	0	0	0	124	124	109	0	0	0	109	109
0.5	34	0	0	0	34	34	70	0	0	0	70	70	82	0	0	1	81	81
0.6	18	0	0	0	18	18	66	0	0	0	66	66	60	0	0	0	60	60
0.7	12	0	0	1	11	11	28	0	0	0	28	28	24	0	0	1	23	23
0.8	8	0	0	1	7	7	12	0	0	0	12	12	18	0	0	0	18	18
0.9	6	0	0	0	6	6	9	0	0	0	9	9	10	0	0	0	10	10
1	7	4	3	2	5	4	2	0	0	0	2	2	5	0	0	0	5	5
1.1	3	3	2	2	1	0	2	2	2	2	0	0	2	2	1	1	1	0
1.2	3	3	2	2	1	0	0	0	0	0	0	0	3	3	3	3	0	0
1.3	3	3	3	3	0	0	1	1	1	1	0	0	2	1	1	2	0	0
1.4	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0
1.5	3	3	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.7	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0
1.8	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.9	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0
2.3	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0
2.5	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.6	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.8	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.2	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	188	22	17	20	168	163	500	3	3	3	497	497	457	10	9	13	444	443
>1v	18	18	14	14	4	0	3	3	3	3	0	0	10	10	9	9	1	0
>2v	4	4	4	4	0	0	0	0	0	0	0	0	1	1	1	1	0	0

Table 1 (Sheet 2 of 2)
South Texas Unit 2 October 98 Outage
Summary of Inspection and Repair For Tubes in Service During Cycle 6

Voltage Bin	Steam Generator D						Composite of All SGs					
	In-Service During Cycle 6				RTS for Cycle 7		In-Service During Cycle 6				RTS for Cycle 7	
	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only	Field Bobbin Indications	RPC Inspected	RPC Confirmed	Indications Repaired	All Indications	Confirmed & Not Inspected Indications Only
0.1	2	0	0	0	2	2	8	0	0	0	8	8
0.2	25	0	0	0	25	25	127	0	0	0	127	127
0.3	84	0	0	0	84	84	345	0	0	2	343	343
0.4	71	0	0	1	70	70	344	0	0	2	342	342
0.5	64	0	0	0	64	64	250	0	0	1	249	249
0.6	29	0	0	0	29	29	173	0	0	0	173	173
0.7	29	0	0	0	29	29	93	0	0	2	91	91
0.8	12	0	0	0	12	12	50	0	0	1	49	49
0.9	11	0	0	0	11	11	36	0	0	0	36	36
1	5	1	1	0	5	5	19	5	4	2	17	16
1.1	1	1	1	1	0	0	8	8	6	6	2	0
1.2	2	2	2	2	0	0	8	8	7	7	1	0
1.3	1	1	1	1	0	0	7	6	6	6	0	0
1.4	0	0	0	0	0	0	1	1	1	1	0	0
1.5	2	2	2	2	0	0	5	5	3	3	2	0
1.6	1	1	1	1	0	0	1	1	1	1	0	0
1.7	0	0	0	0	0	0	1	1	1	1	0	0
1.8	0	0	0	0	0	0	2	2	2	2	0	0
1.9	0	0	0	0	0	0	1	1	1	1	0	0
2.3	1	1	1	1	0	0	2	2	2	2	0	0
2.5	0	0	0	0	0	0	1	1	1	1	0	0
2.6	0	0	0	0	0	0	1	1	1	1	0	0
2.8	0	0	0	0	0	0	1	1	1	1	0	0
4.2	0	0	0	0	0	0	1	1	1	1	0	0
Total	340	9	9	9	331	331	1485	44	38	44	1440	1434
>1 v	8	8	8	8	0	0	40	39	34	34	5	0
>2 v	1	1	1	1	0	0	6	6	6	6	0	0

Table 4-2
South Texas Unit 2 October 1998
TSP ODSCC Indication Distributions for Tubes in Service During Cycle 6

Tube Support Plate	Steam Generator A					Steam Generator B					Steam Generator C				
	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth
02H	77	2.76	0.62	2.23	0.20	179	1.29	0.39	0.67	0.12	166	1.84	0.47	1.40	0.14
03H	74	4.12	0.60	3.41	0.09	170	1.08	0.42	0.69	0.09	142	2.26	0.42	1.86	0.12
04H	24	0.85	0.40	0.27	0.03	115	0.94	0.37	0.35	0.07	102	1.34	0.41	0.98	0.11
05H	12	0.99	0.40	0.20	0.04	33	0.70	0.33	0.35	0.08	28	0.90	0.39	0.34	0.08
06H	1	0.29	0.29	0.00	0.00	1	0.23	0.23	0.03	0.03	15	0.84	0.41	0.31	0.09
07H	0	-	-	-	-	0	-	-	-	-	2	0.49	0.32	0.14	0.08
08H	0	-	-	-	-	2	0.15	0.13	0.02	0.02	0	-	-	-	-
11C	0	-	-	-	-	0	-	-	-	-	1	0.18	0.18	0.05	0.05
22C	0	-	-	-	-	0	-	-	-	-	1	1.23	1.23	-	-
Total	188					500					457				

Tube Support Plate	Steam Generator D					Composite of All SGs				
	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth	Number of Indications	Maximum Voltage	Average Voltage	Largest Growth	Average Growth
02H	164	1.53	0.42	1.20	0.18	586	2.76	0.45	2.23	0.15
03H	126	2.26	0.49	1.44	0.21	512	4.12	0.46	3.41	0.13
04H	27	0.85	0.39	0.65	0.18	268	1.34	0.39	0.98	0.09
05H	14	0.68	0.37	0.38	0.13	87	0.99	0.37	0.38	0.08
06H	8	0.63	0.38	0.34	0.16	25	0.84	0.39	0.34	0.11
07H	1	0.29	0.29	0.15	0.15	3	0.49	0.31	0.15	0.10
08H	0	-	-	-	-	2	0.15	0.13	0.02	0.02
11C	0	-	-	-	-	1	0.18	0.18	0.05	0.05
22C	0	-	-	-	-	1	1.23	1.23	-	-
Total	340					1485				

Table 4-3
South Texas Unit 2 October 98
Signal Growth Statistics For Cycle 6 on an EFPY Basis

Delta Volts	Steam Generator A			Steam Generator B			Steam Generator C			Steam Generator D			Cumulative		
	Cycle 5	Cycle 6		Cycle 5	Cycle 6		Cycle 5	Cycle 6		Cycle 5	Cycle 6		Cycle 5	Cycle 6	
	CPDF	No. of Inds	CPDF	CPDF	No. of Inds[1]	CPDF	CPDF	No. of Inds	CPDF	CPDF	No. of Inds	CPDF	CPDF	No. of Inds	CPDF
-0.2	0.0	1	0.005	0.0	1	0.002	0.0	0	0.0	0.0	0	0.0		2	0.001
-0.1	0.0	5	0.032	0.015	0	0.002	0.011	2	0.004	0.006	0	0.0	0.009	7	0.006
0	0.021	44	0.266	0.215	65	0.132	0.09	49	0.112	0.194	14	0.041	0.137	172	0.122
0.1	0.326	97	0.782	0.738	334	0.8	0.534	289	0.746	0.823	170	0.541	0.62	890	0.722
0.2	0.736	27	0.926	0.974	83	0.966	0.815	94	0.952	0.96	104	0.847	0.879	308	0.929
0.3	0.868	4	0.947	0.99	15	0.996	0.942	16	0.987	0.989	34	0.947	0.952	69	0.976
0.4	0.938	3	0.963	0.99	0	0.996	0.984	1	0.989	0.989	8	0.971	0.977	12	0.984
0.5	0.972	2	0.973	0.995	2	1.0	1.0	1	0.991	0.989	6	0.988	0.99	11	0.991
0.6	0.986	1	0.979	0.995	0			0	0.991	1.0	1	0.991	0.996	2	0.993
0.7	0.993	0	0.979	1.0	0			1	0.993		1	0.994	0.999	2	0.994
0.8	1.0	0	0.979		0			1	0.996		1	0.997	1.0	2	0.995
1		0	0.979		0			1	0.998		1	1.0		2	0.997
1.1		2	0.989		0			0	0.998		0			2	0.998
1.2		0	0.989		0			1	1.0		0			1	0.999
1.5		1	0.995		0			0	1.0		0			1	0.999
2.2		1	1.0		0			0	1.0		0			1	1.0
Total		188			500			456			340			1484	

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Table 4-4
South Texas Unit 2 - October 1998 Outage
Average Voltage Growth During Cycle 6

Voltage Range	Number of Indications	Average Voltage BOC	Average Voltage Growth		Percent Growth	
			Entire Cycle	Per EFPY #	Entire Cycle	Per EFPY #
	Composite of All Steam Generator Data					
Entire Voltage Range	1484	0.31	0.13	0.08	42%	27%
V_{BOC} < .75 Volts	1437	0.29	0.13	0.08	44%	29%
≥ .75 Volts	47	0.93	0.16	0.10	17%	11%
	Steam Generator A					
Entire Voltage Range	188	0.44	0.12	0.08	28%	18%
V_{BOC} < .75 Volts	164	0.36	0.11	0.07	31%	20%
≥ .75 Volts	24	1.00	0.19	0.12	19%	12%
	Steam Generator B					
Entire Voltage Range	500	0.29	0.10	0.06	33%	21%
V_{BOC} < .75 Volts	490	0.28	0.10	0.06	35%	23%
≥ .75 Volts	10	0.85	0.02	0.01	2%	1%
	Steam Generator C					
Entire Voltage Range	456	0.31	0.12	0.08	39%	25%
V_{BOC} < .75 Volts	445	0.30	0.12	0.08	41%	27%
≥ .75 Volts	11	0.89	0.09	0.06	11%	7%
	Steam Generator D					
Entire Voltage Range	340	0.25	0.19	0.12	75%	49%
V_{BOC} < .75 Volts	338	0.25	0.19	0.12	75%	48%
≥ .75 Volts	2	0.80	0.83	0.54	104%	68%

\# Based on Cycle 6 duration of 564.9 EFPD (1.547 EFPY)

Table 4-5
South Texas Unit 2 October 1998
Average Voltage Growth Satatistics
Composite of All Steam Generator Data

Bobbin Voltage Range	Number of Indications	Average Voltage BOC	Average Voltage Growth		Average Percentage Growth	
			Entire Cycle	Per EFPY	Entire Cycle	Per EFPY
	Cycle 6 (1997 - 1998) - 564.9 EFPD					
Entire Voltage Range	1484	0.31	0.13	0.08	42%	27%
V_{BOC} < .75 Volts	1437	0.29	0.13	0.08	44%	29%
≥ .75 Volts	47	0.93	0.16	0.10	17%	11%
	Cycle 5 (1995 - 1997) - 450 EFPD					
Entire Voltage Range	703	0.31	0.12	0.10	39%	31%
V_{BOC} < .75 Volts	696	0.31	0.12	0.10	39%	32%
≥ .75 Volts	7	0.91	0.20	0.16	22%	18%

Table 4-6
South Texas Unit 2 October 1998
Summary of Largest Voltage Growth Rates for BOC-6 to EOC-6

Steam Generator				Bobbin Voltage			RPC	New
SG	Row	Col	Elevation	EOC	BOC	Growth	Confirmed ?	Indication ?
A	18	100	02H	4.12	0.71	3.41	Y	Y
A	19	83	02H	2.76	0.53	2.23	Y	N
C	27	88	03H	2.26	0.4	1.86	Y	Y
A	25	88	03H	2.54	0.88	1.66	Y	Y
A	20	36	02H	2.43	0.78	1.65	Y	Y
D	16	100	03H	2.26	0.82	1.44	Y	Y
C	8	111	02H	1.84	0.44	1.4	Y	Y
C	25	40	03[illegible]	1.62	0.42	1.2	Y	Y
D	20	36	02H	1.42	0.22	1.2	Y	Y
D	16	101	03H	1.44	0.45	0.99	Y	Y
C	17	72	04H	1.34	0.36	0.98	Y	Y
D	16	100	[illegible]	[illegible]	0.63	[illegible]	Y	Y
A	25	40	02H	1.78	0.97	0.81	Y	Y
A	24	104	02H	1.23	0.48	0.75	Y	Y
C	15	86	02H	1.14	0.41	0.73	Y	Y
D	29	43	03H	0.99	0.27	0.72	Y	Y
A	25	85	02H	1.29	0.59	0.7	Y	Y
D	18	40	02H	0.82	0.12	0.7	N	Y
B	13	113	03H	1.08	0.39	0.69	Y	Y
B	10	102	02H	0.85	0.18	0.67	N	Y
D	19	38	03H	1.1[illegible]	0.45	0.67	Y	Y
D	24	68	04H	0.85	0.2	0.65	N	Y
D	29	21	02H	0.79	0.15	0.64	N	Y
D	18	101	03H	1.3	0.67	0.63	Y	Y
D	23	74	03H	0.91	0.3	0.61	N	Y
D	42	89	03H	0.8	0.21	0.59	N	Y
A	24	106	02H	0.98	0.4	0.58	N	Y
C	34	76	03H	1.01	0.46	0.55	Y	Y
A	21	104	02H	1.0[illegible]	0.4[illegible]	0.53	Y	Y
D	19	104	03H	1.03	0.5	0.53	Y	Y

Table 4-7
Probe Wear and Analyst Variability - Tabulated Values

Analyst Variability Std. Dev = 10.3% Mean = 0.0% No Cutoff	
Value	Cumul. Prob.
-40.0%	0.00005
-38.0%	0.00011
-36.0%	0.00024
-34.0%	0.00048
-32.0%	0.00095
-30.0%	0.00179
-28.0%	0.00328
-26.0%	0.00580
-24.0%	0.00990
-22.0%	0.01634
-20.0%	0.02608
-18.0%	0.04027
-16.0%	0.06016
-14.0%	0.08704
-12.0%	0.12200
-10.0%	0.16581
-8.0%	0.21867
-6.0%	0.28011
-4.0%	0.34888
-2.0%	0.42302
0.0%	0.50000
2.0%	0.57698
4.0%	0.65112
6.0%	0.71989
8.0%	0.78133
10.0%	0.83419
12.0%	0.87800
14.0%	0.91296
16.0%	0.93984
18.0%	0.95973
20.0%	0.97392
22.0%	0.98366
24.0%	0.99010
26.0%	0.99420
28.0%	0.99672
30.0%	0.99821
32.0%	0.99905
34.0%	0.99952
36.0%	0.99976
38.0%	0.99989
40.0%	0.99995

Probe Wear Variability Std. Dev = 7.0% Mean = 0.0% Cutoff at +/- 15%	
Value	Cumul. Prob.
< -15.0%	0.00000
-15.0%	0.01606
-14.0%	0.02275
-13.0%	0.03165
-12.0%	0.04324
-11.0%	0.05804
-10.0%	0.07656
-9.0%	0.09927
-8.0%	0.12655
-7.0%	0.15866
-6.0%	0.19568
-5.0%	0.23753
-4.0%	0.28385
-3.0%	0.33412
-2.0%	0.38755
-1.0%	0.44320
0.0%	0.50000
1.0%	0.55680
2.0%	0.61245
3.0%	0.66588
4.0%	0.71615
5.0%	0.76247
6.0%	0.80432
7.0%	0.84134
8.0%	0.87345
9.0%	0.90073
10.0%	0.92344
11.0%	0.94196
12.0%	0.95676
13.0%	0.96835
14.0%	0.97725
15.0%	0.98394
> 15.0%	1.00000

Table 4-8
South Texas Unit 2 1998 EOC-6 Evaluation for Probability of Prior Cycle Detection
Composite of All Steam Generator Data

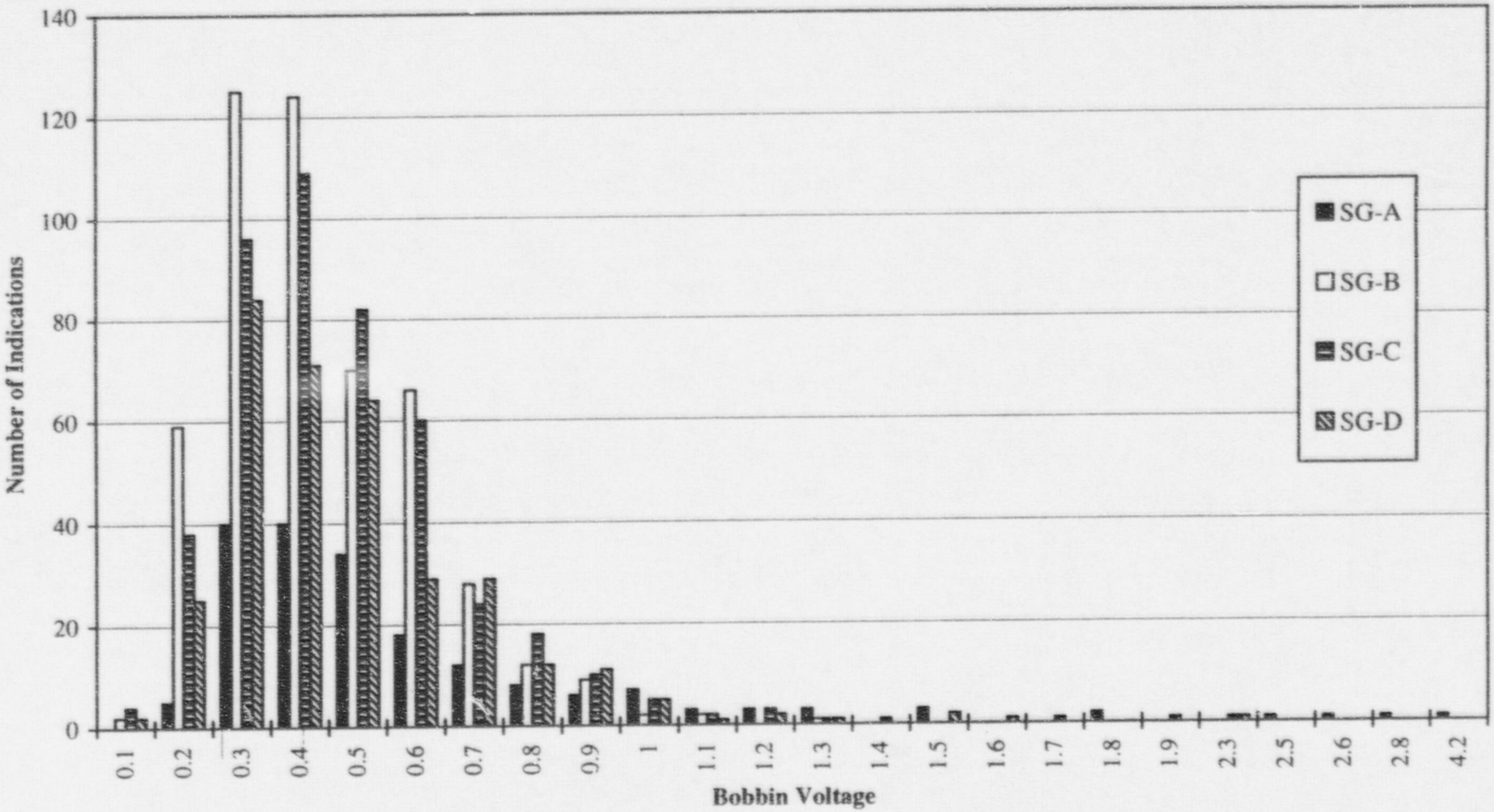
Voltage Bin	New Indications		1998 Bobbin, Field Call in 1997 Inspection		1997 Inspection Bobbin	POPCD			
	1998 Inspection RPC Confirmed	1998 Inspection RPC Confirmed plus not Inspected	1998 Inspection RPC Confirmed	1998 Inspection RPC Confirmed plus not Inspected	1997 Inspection Confirmed and Plugged	RPC Confirmed		RPC Confirmed Plus Not Inspected	
						Frac.	Count	Frac.	Count
> 0 - 0.2	0	414	0	45	32	1.0	32 / 32	0.157	77 / 491
0.2 - 0.4	4	531	1	196	289	0.986	290 / 294	0.477	485 / 1016
0.4 - 0.6	9	161	2	52	203	0.958	205 / 214	0.613	255 / 416
0.6 -1.0	16	57	0	16	104	0.867	104 / 120	0.678	120 / 177
1.0 - 1.5	6	6	0	0	16	0.727	16 / 22	0.727	16 / 22
1.5 - 2.0	0	0	0	0	1	1.000	1 / 1	1.000	1 / 1
TOTAL	35	1169	3	309	645				
> 1V	6	6	0	0	17				

Table 4-9
South Texas Unit 2
Analysis of RPC Data from 1997 and 1998 Inspections
Combined Data from All Steam Generators

Group of Indications	Total 1997 Inspection Bobbin Indication	Total 1998 Inspection Bobbin Indication	Total 1998 Inspection RPC Inspected	Total 1998 Inspection RPC Confirmed	Percent 1998 Inspection RPC Confirmed
Less than or Equal to 1.0 Volt in 1998 inspection					
1997 Inspection Bobbin Left in Service	345	306	0	0	-
- 1997 Inspection RPC Confirmed	0	0	0	0	-
- 1997 Inspection RPC NDD	306	306	0	0	-
- 1997 Inspection RPC Not Inspected	0	0	0	0	-
- No 1998 Inspection Bobbin *	39	-	-	-	-
New 1998 Inspection Indication	-	1139	5	4	80.0
Sum of All 1998 Inspection Indication	345	1445	5	4	80.0
Greater than 1.0 Volt in 1998 Inspection					
1997 Inspection Bobbin Left in Service	4	4	4	3	75.0
- 1997 Inspection RPC Confirmed	0	0	0	0	-
- 1997 Inspection RPC NDD	4	4	4	3	75.0
- 1997 Inspection RPC Not Inspected	0	0	0	0	-
- No 1998 Inspection Bobbin *	0	-	-	-	-
New 1998 Inspection Indication	-	35	35	31	88.6
Sum of All 1998 Inspection Indication	4	39	39	34	87.2
All Voltages in 1998 Inspection					
1997 Inspection Bobbin Left in Service	349	310	4	3	75.0
- 1997 Inspection RPC Confirmed	0	0	0	0	-
- 1997 Inspection RPC NDD	310	310	4	3	75.0
- 1997 Inspection RPC Not Inspected	0	0	0	0	-
- No 1998 Inspection Bobbin *	39	-	-	-	-
New 1998 Inspection Indication	-	1174	40	35	87.5
Sum of All 1998 Inspection Indication	349	1484	44	38	86.4

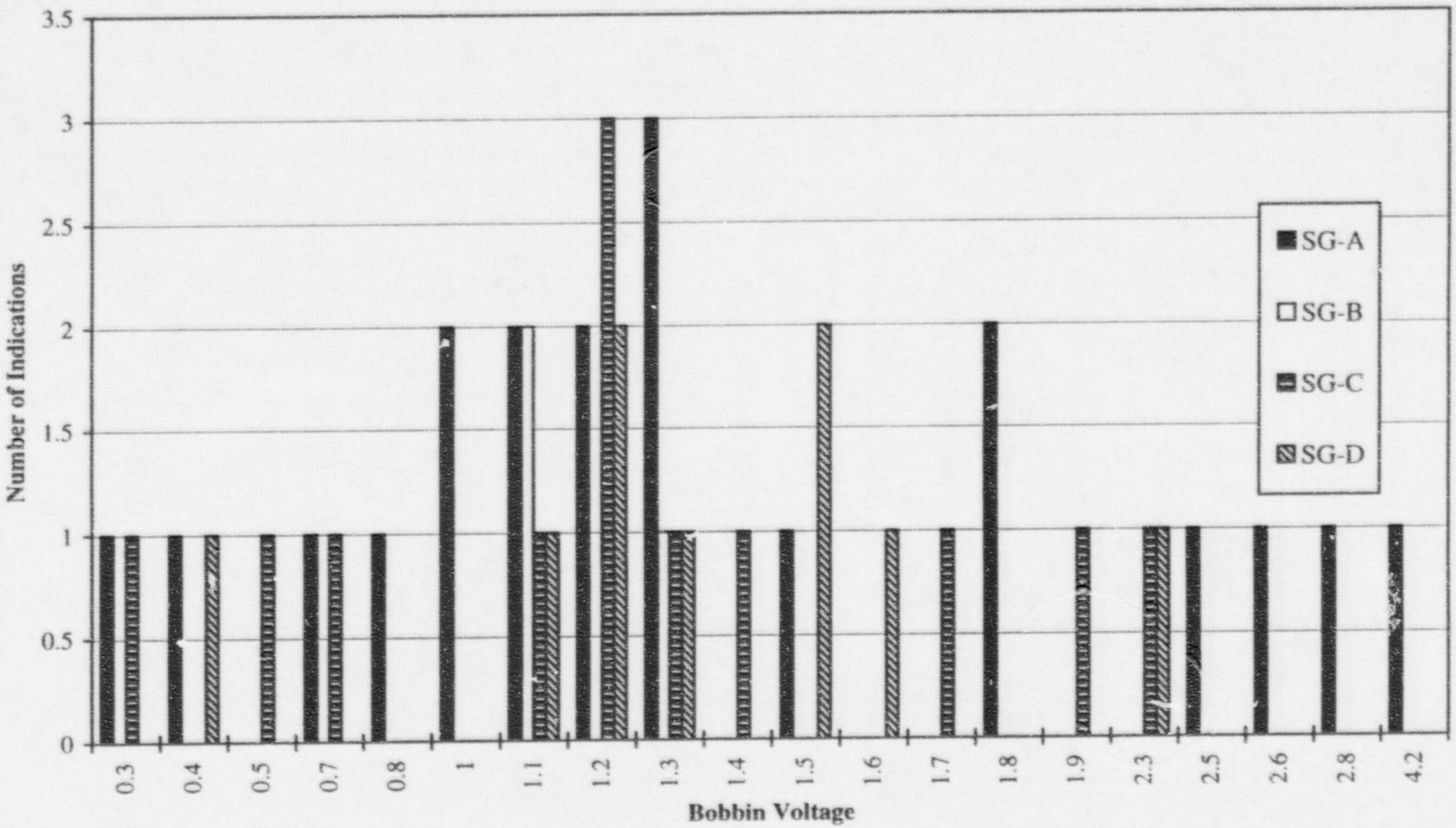
* Indications split is based on 1997 Inspection bobbin voltage

Figure 4-1
South Texas Unit 2 October 1998 Outage
Bobbin Voltage Distributions at EOC-6 for Tubes in Service During Cycle 6



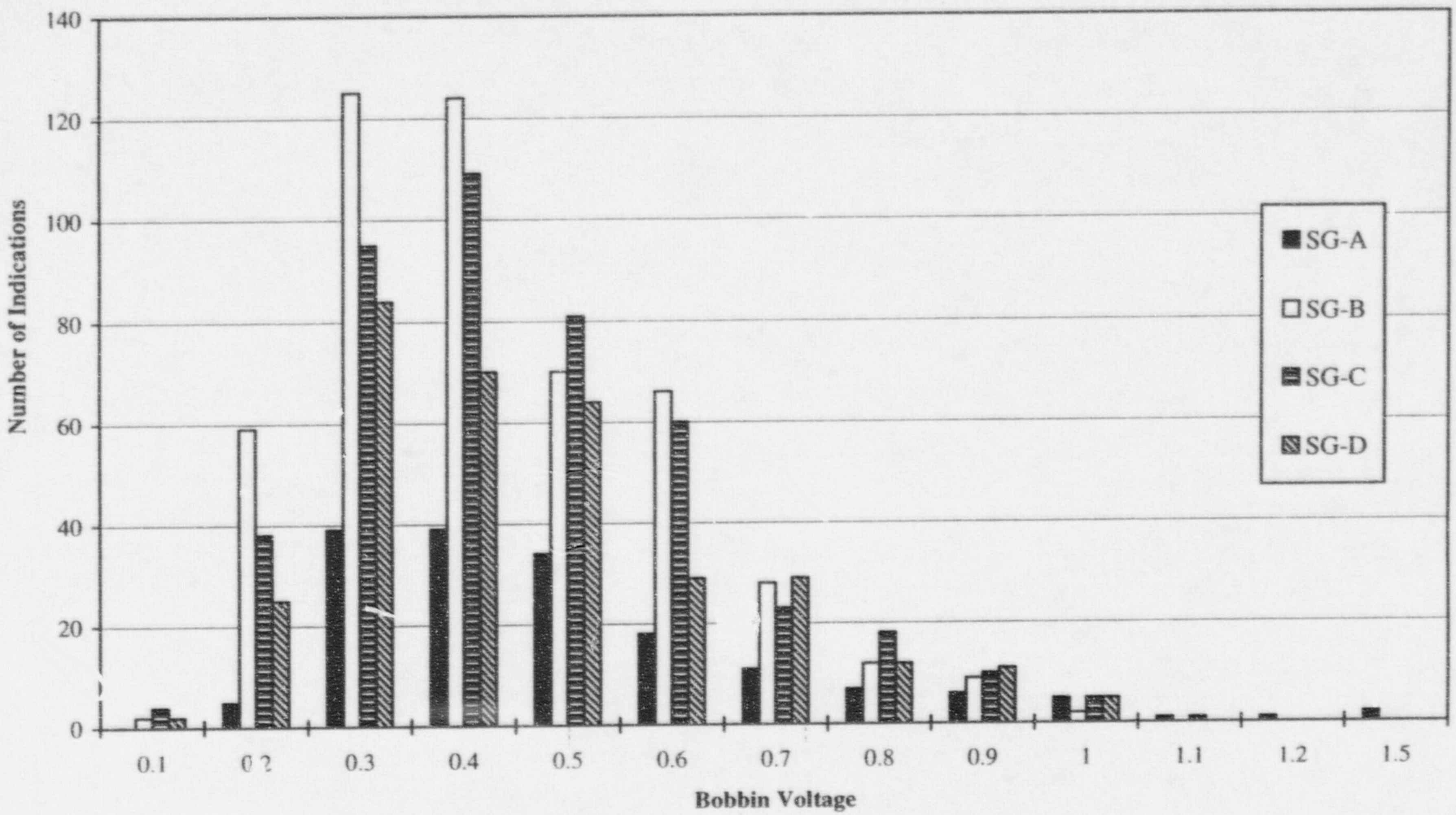
BobnrpcFig1]

Figure 4-2
South Texas Unit 2 October 1998 Outage
Bobbin Voltage Distribution for Tubes Plugged After Cycle 6 Service



BobnrpcFig2

Figure 4-3
South Texas Unit 2 October 1998 Outage
Bobbin Voltage Distributions for Tubes Returned to Service for Cycle 7



BobnrpcFig3

Figure 4-4
South Texas Unit 2 - October 1998
ODSCC Axial Distributions for Tubes in Service During Cycle 6

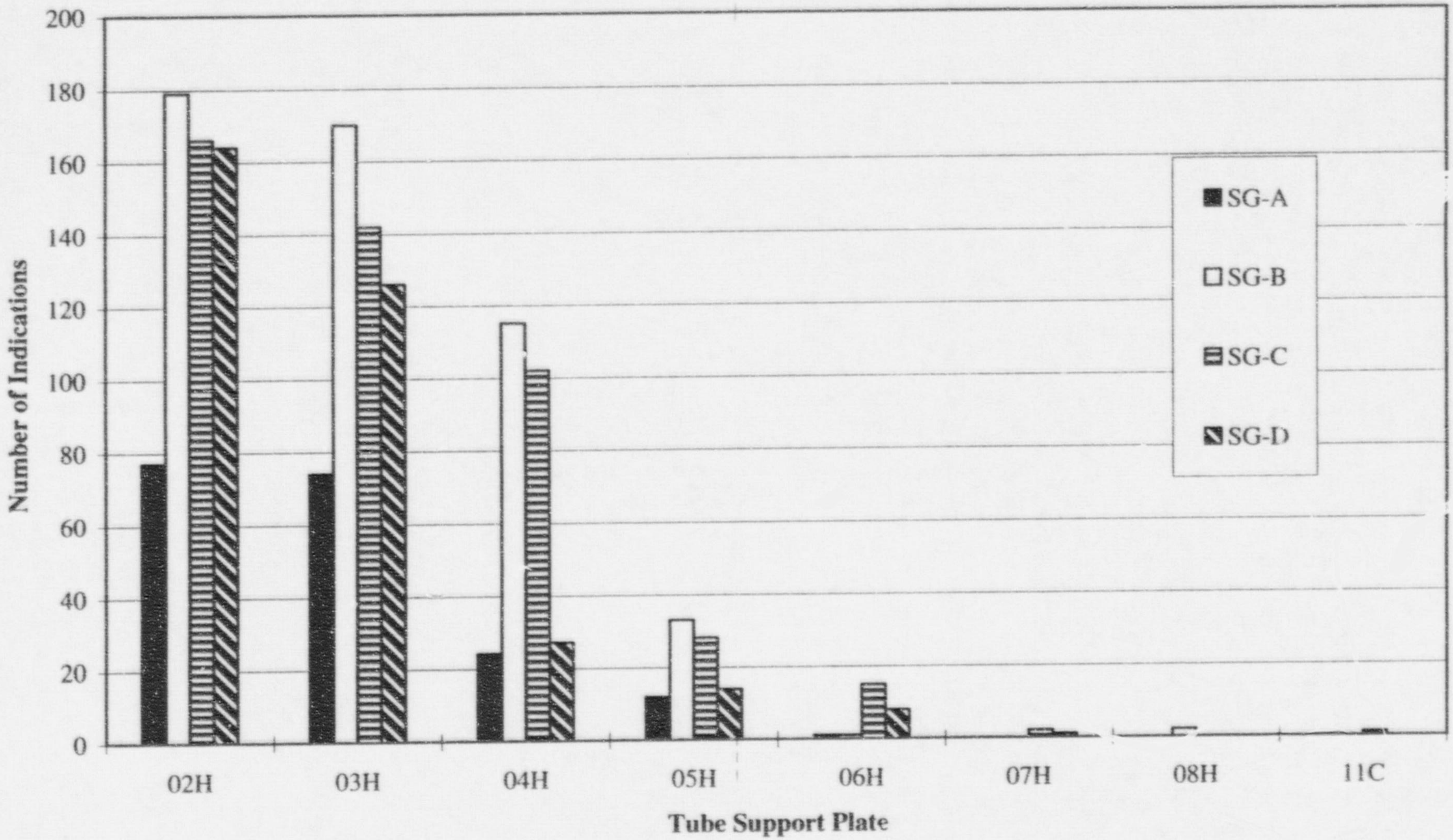


Figure 4-5
South Texas Unit 2Cycle 6 (July 1997 to Oct. 1998)
Cumulative Probability Distributions for Voltage Growth on an EFPY Basis

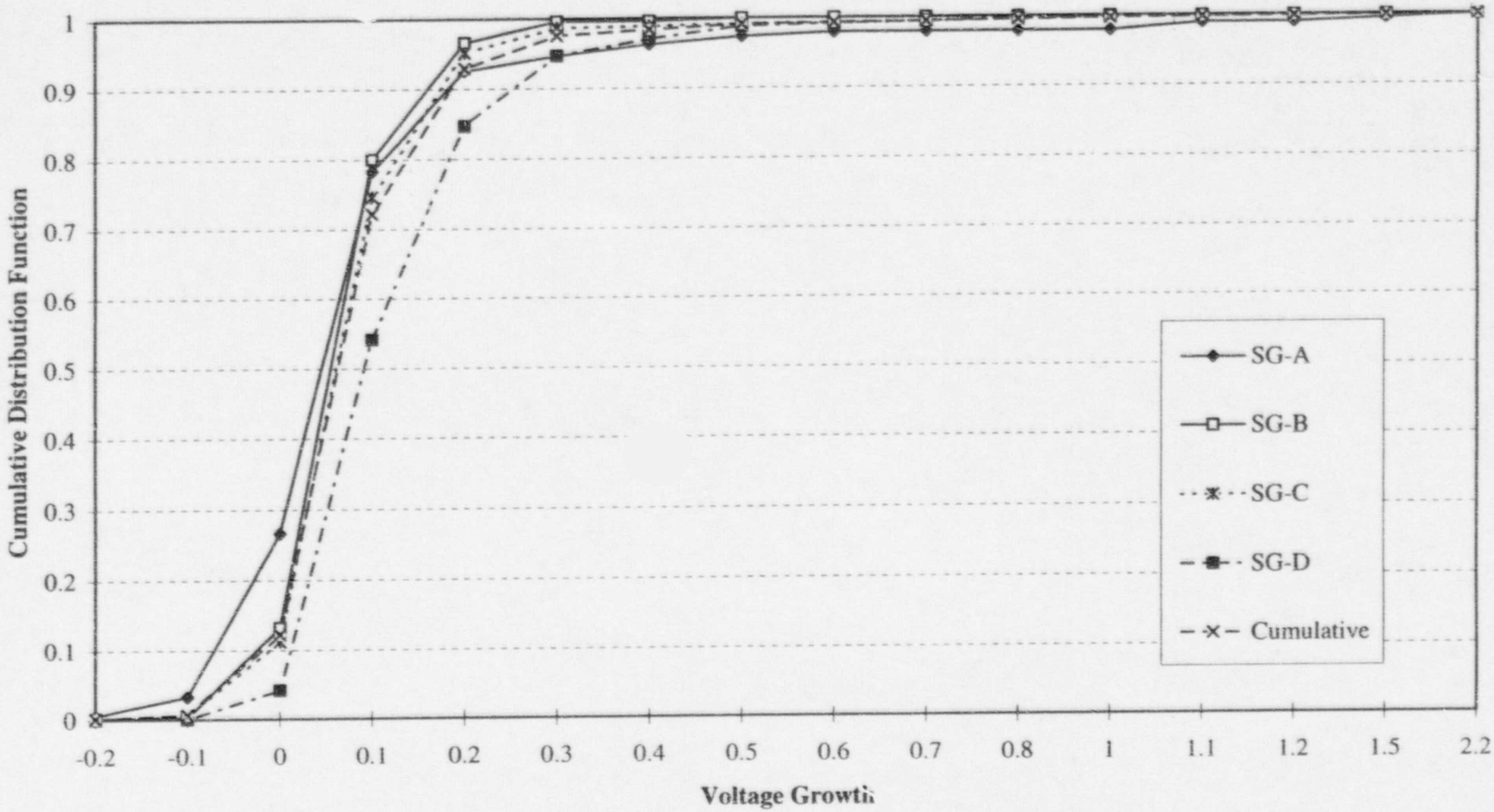


Figure 4-6
South Texas Unit -1 October 1998 Outage
Voltage Growth During Cycle 6 vs BOC-6 Voltage

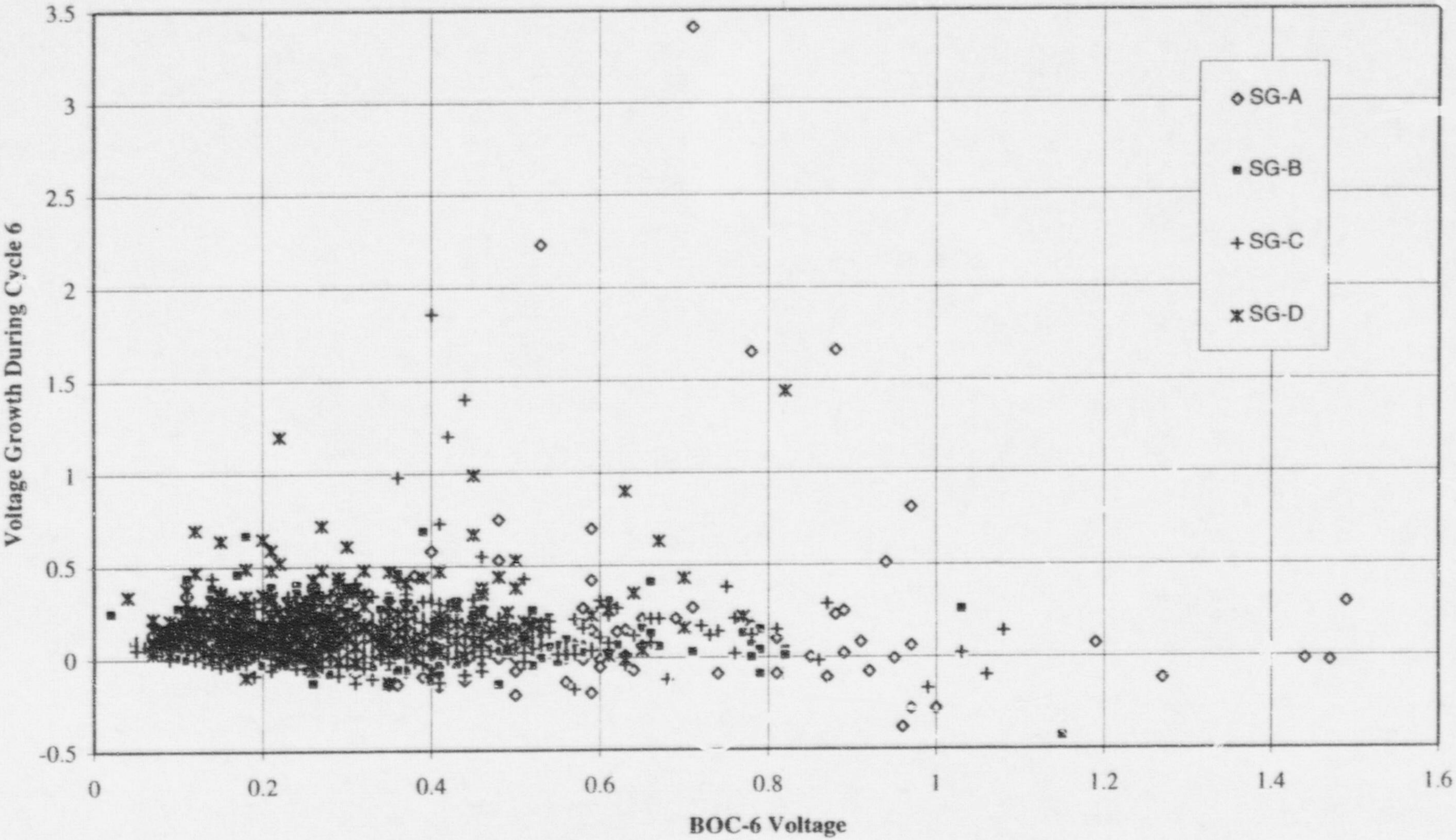


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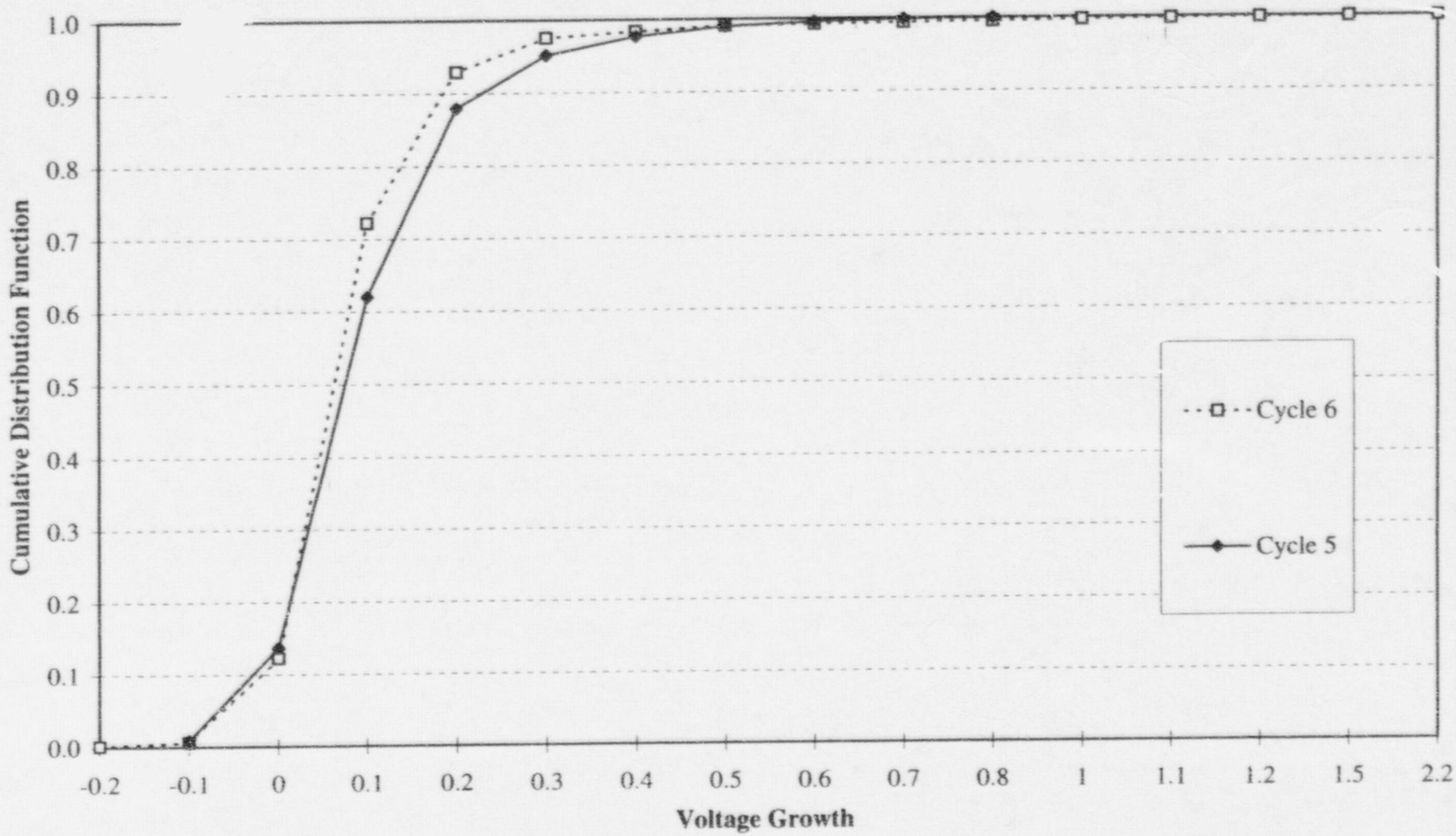
Figure 4-7
South Texas Unit 2 - October 1998
Bobbin Signal Growth History - Cumulative Probability Distributions on an EFPY Basis
Composite of All Steam Generators



Growth Fig3 12/21/98 11:18 AM

Figure 4-8
NDE Uncertainty Distributions

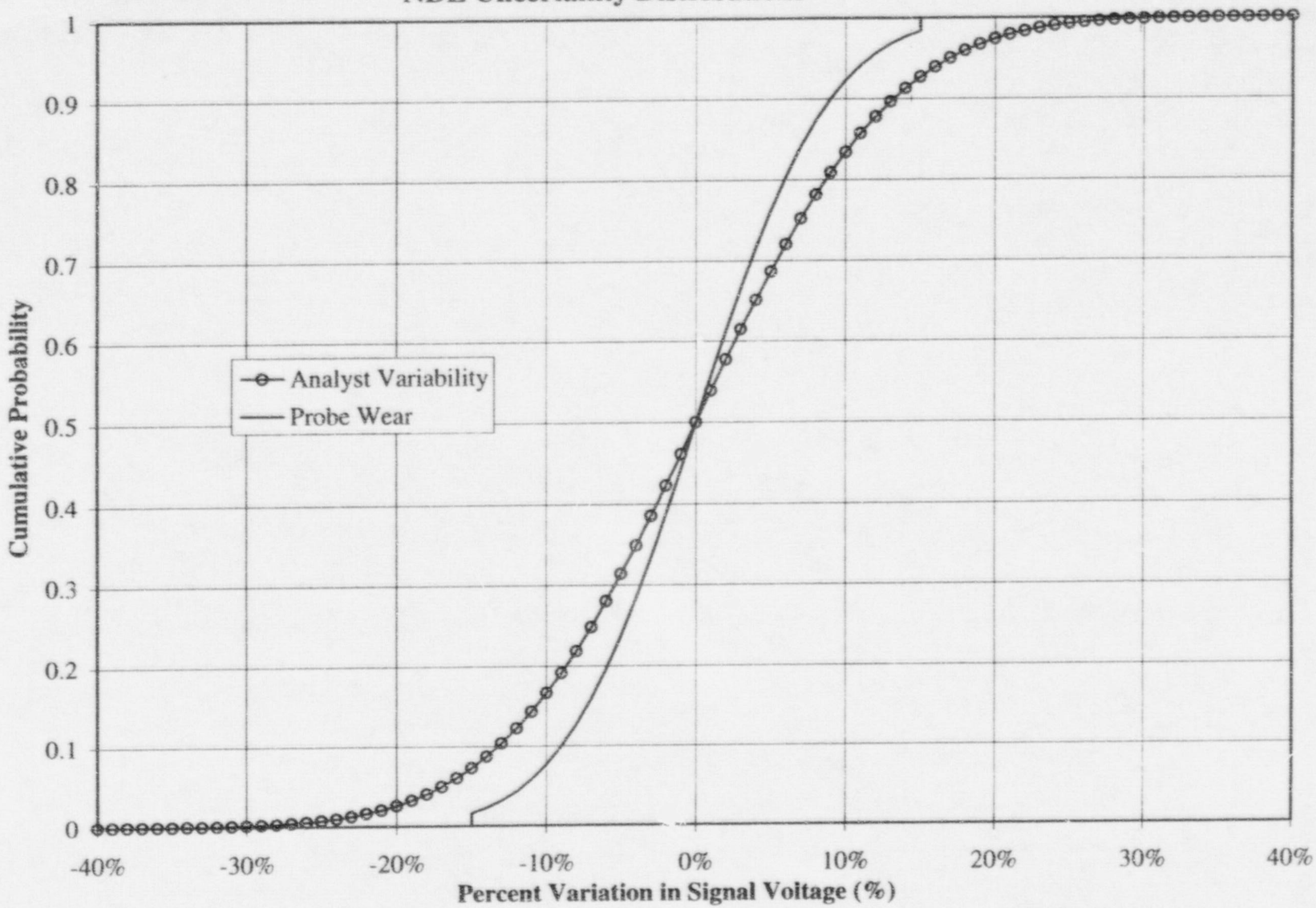


Figure 4-9
South Texas Unit 2
1998 EOC-6 Evaluation for POPCD at EOC-5

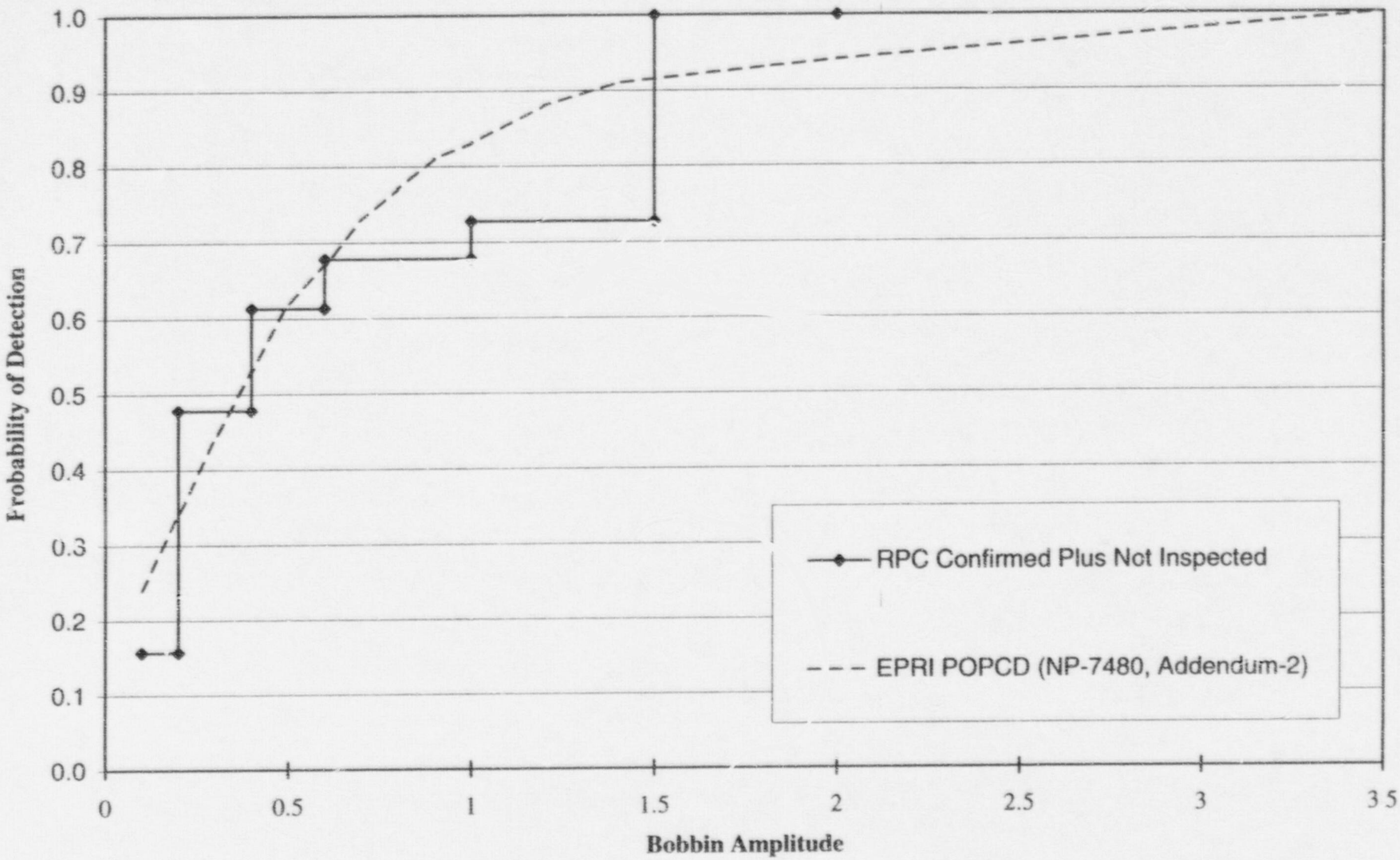


Figure 4-10
South Texas Unit-2 -- EOC-6 Inspection
Comparison of Worn Probe Voltage Against New Probe Voltage

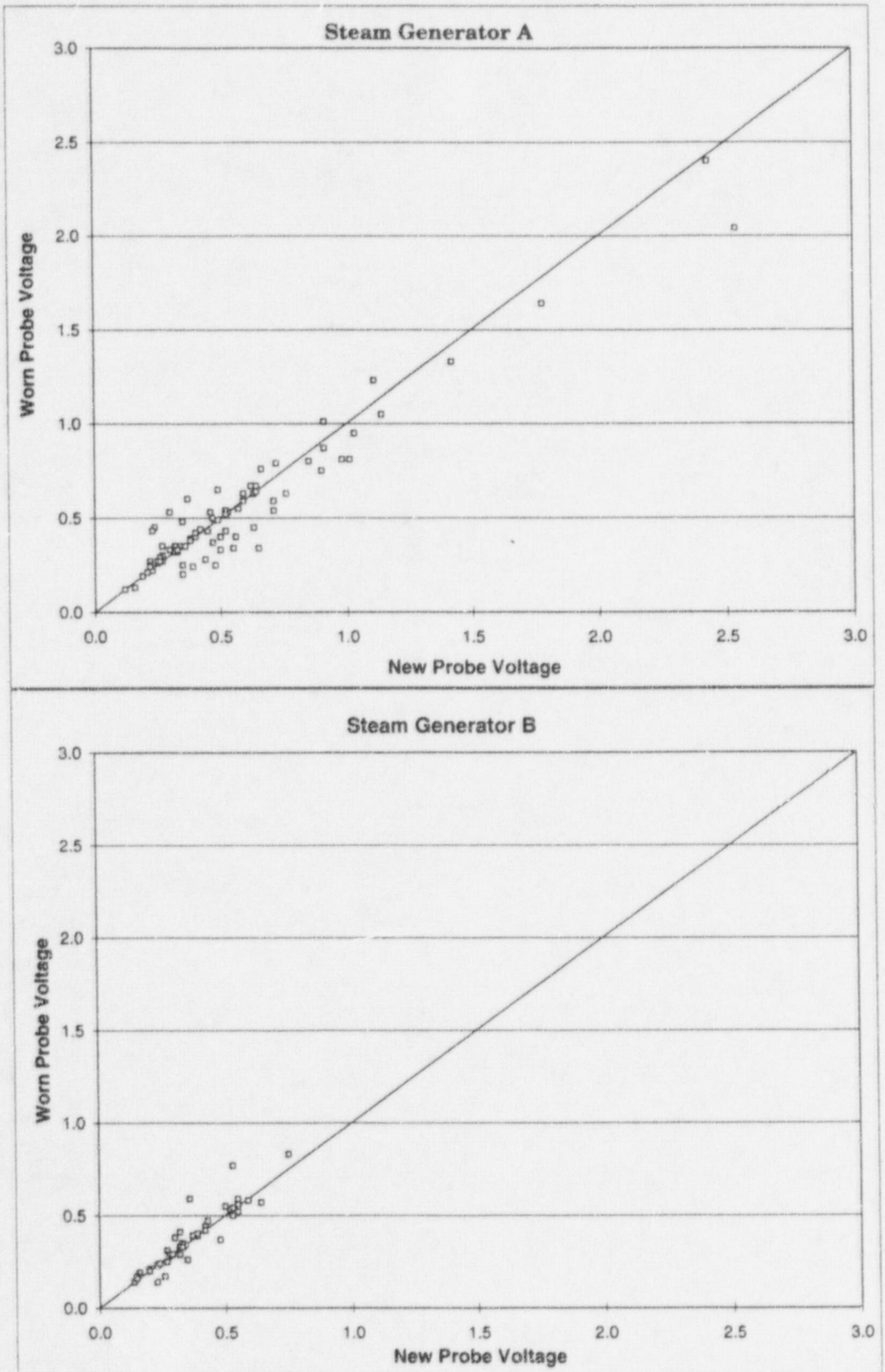
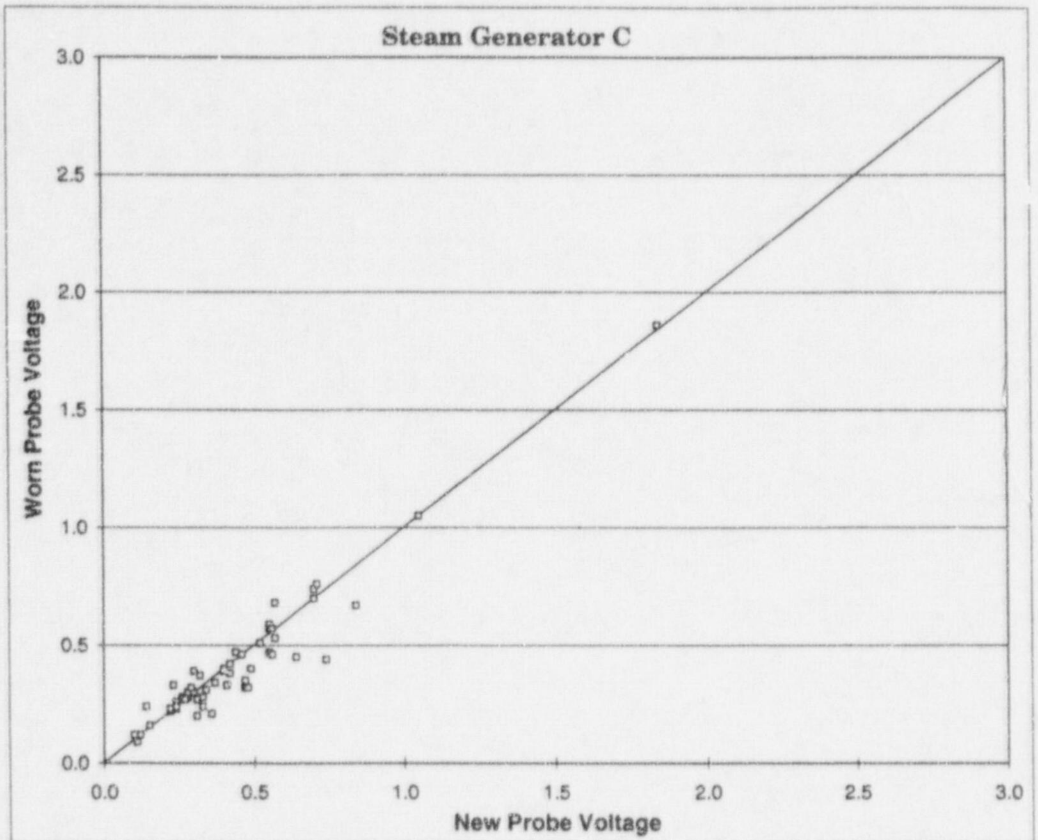


Figure 4-11
South Texas Unit-2 -- EOC-6 Inspection
Comparison of Worn Probe Voltage Against New Probe Voltage



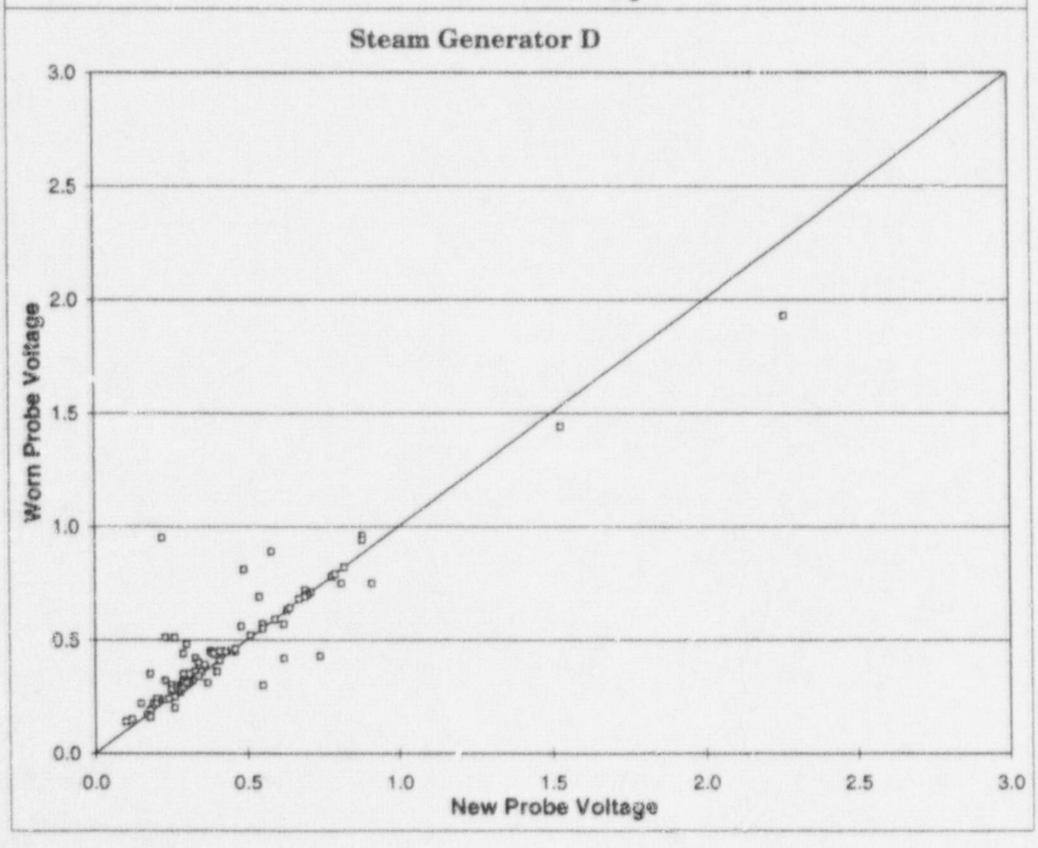
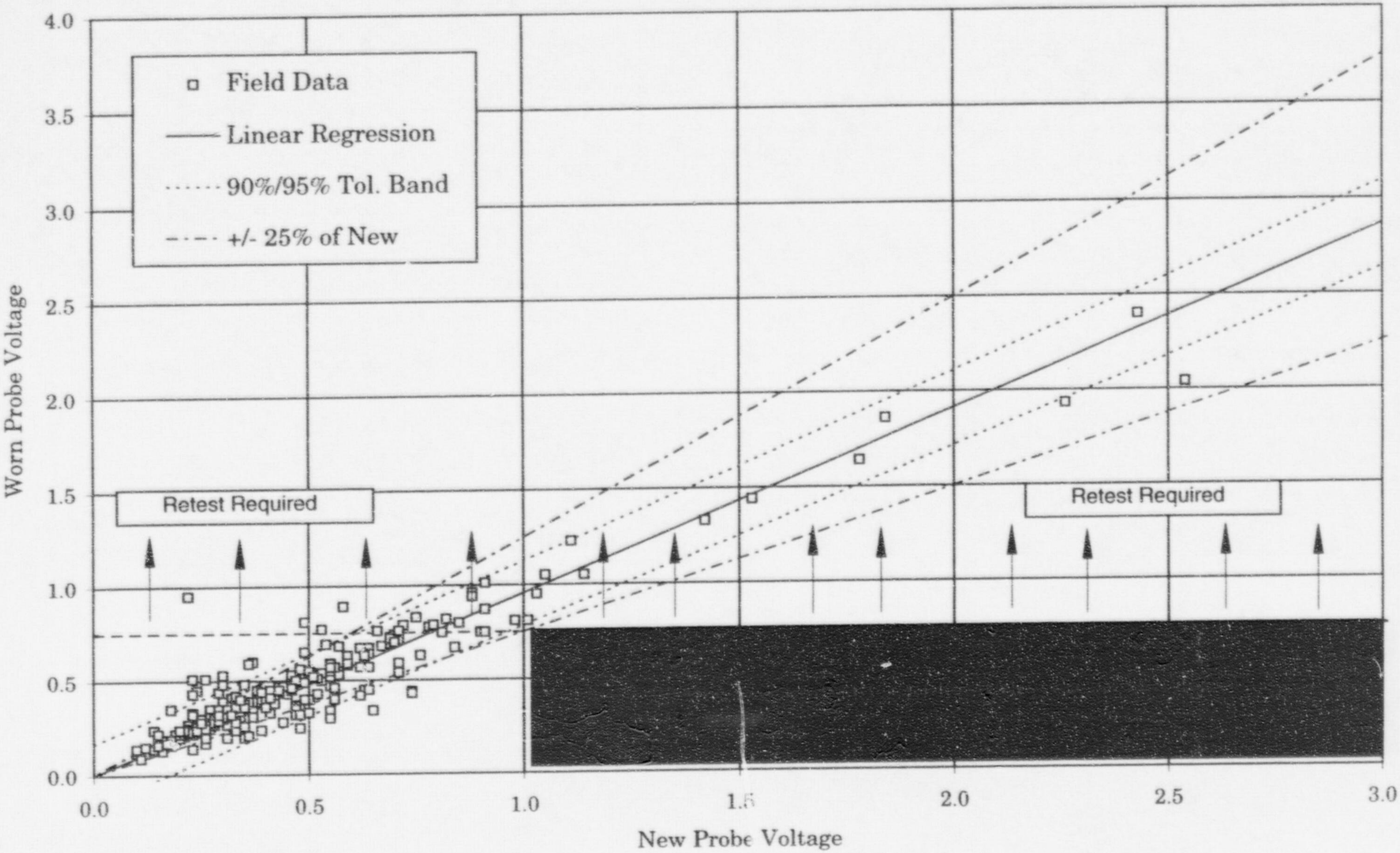


Figure 4-12
South Texas Unit-2 October 1998
Worn Probe Volts vs New Probe Volts



[Probwear] Fig4-12 1/11/99 4:36 PM

5.0 Database Applied for Leak and Burst Correlations

The database used for the leak and burst correlations that are applied in the analyses of this report is the same as the voltage-based repair criteria database for ¾" tubes approved recently by the NRC (Reference 9-5), and it is documented in Reference 9-4. Plant S pulled tube indication R28C41 is included in the leak rate correlation at a revised SLB leak rate of 1250 lph consistent with Reference 9-5 Leak rate data for Model Boiler specimens 598-3 and 604-2 are excluded from the repair criteria database based on application of EPRI data exclusion Criterion 3a which permits exclusion of leak rate data that lie below the one-sided, 99-percent statistical confidence intervals of the mean regression line relating leak rate to both throughwall crack length and bobbin coil voltage.

South Texas pulled tube data from 1993 and 1995 inspections are included in the voltage-based repair criteria database. The database meets the NRC requirement that the p value obtained from the regression analysis of leak rate be less than or equal to 5%. Therefore, a SLB leak rate versus voltage correlation is applied for the leak rate analyses of this report.

The following are the correlations for burst pressure, probability of leakage and leak rate used in this report (Reference 9-4).

$$\text{Burst Pressure } (ksi) = 7.4234 - 2.9920 \times \log(Volts)$$

$$\text{Probability of Leak} = \frac{1}{1 + e^{\left(5.1721 - 8.6705 \times \log(volts)\right)}}$$

$$\text{Leak Rate } (l/hr) = 10^{\left(-2.119 + 3.3162 \times \log(volts)\right)}$$

Additional leakage and burst pressure data are available from 3 TSP indications pulled from South Texas Unit-2 SGs during this outage. Two of the indications are in tube R18C100 in SG-A (TSPs 2 and 3) and the other indication in tube R19C83 of SG-A (TSP 2). An evaluation of the effects of adding the new South Texas Unit-2 data to the reference database in Reference 9-4 (described earlier in Section 3.3) indicates that the burst pressure, leak rate and the probability of leak correlations to the common logarithm of the bobbin amplitude would not be significantly changed. Therefore, SLB leak rates and burst probability analyses were carried out using the reference database presented in Reference 9-4. As a sensitivity study, EOC-7 projections for the limiting SG (SG-A) were also calculated using leak and burst correlation based on an updated base that included the data from the above pulled specimens, and those results indicate are presented in Section 8.

The upper voltage repair limit applied at the EOC-6 inspection, documented in Reference 9-2, was developed using the latest NRC-approved database presented in Reference 9-4. The structural limit (V_{sl}) for the TSP indications established using 3 times normal operation ΔP value (3675 psid) is 5.45 volts, and V_{sl} for the FDB intersections using 1.43 times the SLB ΔP of 2405 psid is 4.47 volts. The allowance for voltage growth used is 49%/EFPY, which is the highest average growth rate on an individual SG basis for South Texas Unit-2 Cycle 5 operation, which is above the minimum value (30%/EFPY) specified in the Generic Letter 95-05. For the expected 0.9 EFPY (329 EFPD) for Cycle 7, the growth allowance becomes 45%. The allowance for NDE uncertainty is 20% per Generic Letter 95-05. The upper voltage repair limits then becomes 3.30 volts for TSP indications and 2.71 volts for FDB indications. These values were applied at the EOC-6 inspection to assure that indications exceeding these limits were repaired independent of RPC confirmation.

6.0 SLB Analysis Methods

Monte Carlo analyses are used to calculate the SLB leak rates and tube burst probabilities for both actual EOC-6 and projected EOC-7 voltage distributions. The Monte Carlo analyses account for parameter uncertainty. The analysis methodology is described in the Westinghouse generic methods report of Reference 9-3, and it is consistent with the methodology applied to obtain the leak rate and tube burst probability results presented in the last 90-day report for Unit-1 (Reference 9-6)

In general, the methodology involves application of correlations for burst pressure, probability of leak and leak rate to a measured or calculated EOC distribution to estimate the likelihood of tube burst and primary-to-secondary leakage during a postulated SLB event. NDE uncertainties and uncertainties associated with burst pressure, leak rate probability and leak rate correlations are explicitly included by considering many thousands of voltage distributions through a Monte Carlo sampling process. The voltage distributions used in the projection analyses for the next operating cycle are obtained by applying growth data to the BOC distribution. The BOC voltage distributions include an adjustment for detection uncertainty and occurrence of new indications, in addition to the adjustments for NDE uncertainties. Comparisons of projected EOC voltage distributions with actual distributions after a cycle of operation have shown that the Monte Carlo analysis technique yields conservative estimates for EOC voltage distributions and as well as leak and burst results based on those distributions. Equation 3.5 in Reference 9-3 was used to determine the true BOC voltage.

7.0 Bobbin Voltage Distributions

This section describes the salient input data used to calculate EOC bobbin voltage distributions and presents results of calculations to project EOC-7 voltage distributions. Also, EOC-6 voltage projections performed during the last outage based on EOC-6 inspection bobbin voltage data are compared with the actual bobbin distributions from the current inspection.

7.1 Calculation of Voltage Distributions

The analysis for EOC voltage distribution starts with a cycle initial voltage distribution which is projected to the end of cycle conditions based on the growth rate and the anticipated cycle operating period. The number of indications assumed in the analysis to project EOC voltage distributions, and to perform tube leak rate and burst probability analyses, is obtained by adjusting the number of reported indications to account for detection uncertainty and birth of new indications over the projection period. This is accomplished by using a POD factor, which is defined as the ratio of the actual number of indications detected to total number of indications present. A conservative value is assigned to POD based on historic data, and the value used herein is discussed in Section 7-2. The calculation of projected bobbin voltage frequency distribution is based on a net total number of indications returned to service, defined as follows.

$$N_{Tot\ RTS} = N_i / POD - N_{repaired} + N_{deplugged}$$

where,

$N_{Tot\ RTS}$	=	Number of bobbin indications being returned to service for the next cycle,
N_i	=	Number of bobbin indications (in tubes in service) identified after the previous cycle,
POD	=	Probability of detection,
$N_{repaired}$	=	Number of N_i which are repaired (plugged) after the last cycle,
$N_{deplugged}$	=	Number of indications in tubes deplugged after the last cycle and returned to service in accordance with voltage-based repair criteria.

There are no deplugged tubes returned to service at BOC-7; therefore, $N_{deplugged} = 0$.

The methodology used in the projection of bobbin voltage frequency predictions is described in Reference 9-3, and it is same as that used in performing EOC-8 predictions during the last (EOC-7) outage for Unit-1 (Reference 9-6). Salient input data used for projecting EOC-7 bobbin voltage frequency are further discussed below.

7.2 Probability of Detection (POD)

The Generic Letter 95-05 (Reference 9-1) requires the application of a constant POD value of 0.6 to define the BOC distribution for EOC voltage projections, unless an alternate POD is approved by the NRC. A POD value of 1.0 represents the ideal situation where all indications are detected. A voltage-dependent POD would a more accurate prediction of voltage distributions consistent with voltage-based repair criteria experience. In this report both NRC mandated constant POD of 0.6 as well as a voltage-dependent POD developed for EPRI (POPCD) are used. The EPRI POPCD is developed by analyses of 18 inspections in 10 plants and is presented in Table 7-4 of Reference 9-4. The POPCD values applied represent a lower 95% confidence bound, and their distribution is graphically illustrated in Figure 7-1.

7.3 Limiting Growth Rate Distribution

As discussed in Section 4.2, the NRC guidelines in Generic Letter 95-05 stipulate that the more conservative growth rate distributions from the past two inspections should be utilized for projecting EOC distributions for the next cycle. It is evident from Table 4-5 that the average growth rate/EFPY for Cycles 5 and 6 are comparable, with Cycle 5 having a slightly higher value. However, Cycle 6 data includes 3 growth values over 1 volt and a value over 2.1 volts while the growth rates for Cycle 5 are all equal to or less than 1 volt (see Table 4-3 and Figure 4-7). Hence, SLB leak rate and tube burst probability projection for the EOC-7 condition based on the Cycle 6 data would yield more conservative results; therefore, Cycle 6 growth distribution would be applied to obtain EOC-7 projections.

As noted in Section 4.2, the Cycle 6 growth rates for SGs A and D are higher than the composite growth distribution and, per the methodology recommended in Reference 9-3, SG-specific growth rates are to be used for SGs A and D while the composite growth rates should be applied for SGs B and C. The growth data for SG-D does not include any of the top 4 growths observed for Cycle 6. Since a few relatively high growth values found in each cycle can be expected to occur randomly in any SG, it is not considered highly improbable that highest growth for the ongoing cycle would occur in SG-D. To account for such a possibility and thus provide additional conservatism, the top 3 growth values for Cycle 6 were added to the SG-specific growth distribution applied to the EOC-7 projection for SG-D.

7.4 Cycle Operating Period

The operating periods used in the growth rate/EFPY calculations and voltage projections are as follows.

Cycle 6	-	BOC-6 to EOC-6	-	564.9 EFPD or 1.55 EFPY (actual)
Cycle 7	-	BOC-7 to EOC-7	-	374 EFPD or 1.02 EFPY (estimated)

7.5 Projected EOC-7 Voltage Distribution

Calculations for EOC-7 bobbin voltage projections were performed for all four SGs based on the EOC-6 distributions shown in Table 7-2. The BOC distributions were adjusted to account for probability of detection as described above, and the adjusted number of indications at BOC-8 are also shown in Table 7-2. Calculations were performed using a constant POD of 0.6 as well as the EPRI POPCD distribution (presented in Table 7-1). As discussed in Section 7-2, EOC-6 growth rates shown in Table 4-3, were applied. The EOC-7 voltage distributions thus projected for all four SGs are summarized on Table 7-3. These results are also shown graphically on Figures 7-2 to 7-5. In general, results based on a constant POD of 0.6 are more conservative than those using the voltage-dependent EPRI POPCD.

7.6 Comparison of Actual and Projected EOC-6 Voltage Distributions

Table 7-4, and Figures 7-6 and 7-7 provide a comparison of the EOC-6 actual measured bobbin voltage distributions with the corresponding projections performed using the last (EOC-5) inspection bobbin voltage data. The EOC-6 projections, originally presented in Reference 9-2, are based on a constant POD of 0.6 and the assumption that a 1.0-volt repair criteria was applied during the EOC-5 inspection. However, "plug-on-detection" criterion was actually applied in the EOC-5 inspection and, therefore, a large number indications under 1 volt confirmed by RPC were repaired. Therefore, the actual number of indications found at EOC-6 in all SGs are significantly below the projections presented in Reference 9-2. However, as projected SG-B was found to have the largest number of indications and SG-A was confirmed to have the largest number of indications over 1 volt. The actual measured voltages include 3 values above 2.5 volts that were not projected.

A comparison of the actual and projected voltage distributions in Figures 7-6 and 7-7 show that in general the indication population above 0.5 volts is substantially overestimated in the projections based on a constant POD of 0.6. This POD value is conservative for voltages above about 0.5 volt but non-conservative below 0.5 volt as seen in Figure 7-1.

Table 7-1
EPRI POPCD Distribution
Based on Data from 15 Inspections in 8 Plants

Voltage Bin	EPRI POPCD#
0.1	0.24
0.2	0.34
0.3	0.44
0.4	0.53
0.5	0.62
0.6	0.67
0.7	0.73
0.8	0.77
0.9	0.81
1	0.83
1.2	0.88
1.4	0.91
1.6	0.92
1.8	0.93
2	0.94
3	0.98
3.5	1.0

Data from Table 7-4 in Reference 8-4.

Table 7-2 (Sheet 1 of 2)
South Texas Unit 2 October 1998
EOC-6 Bobbin and Assumed BOC-7 Bobbin Distributions in
SLB Leak Rate and Tube Burst Analyses

Voltage Bin	Steam Generator A				Steam Generator B			
	EOC - 6		BOC - 7		EOC - 6		BOC - 7	
	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD
0.1	0	0	0.00	0.00	2	0	3.33	8.33
0.2	5	0	8.33	14.71	59	0	98.33	173.53
0.3	40	1	65.67	89.91	125	0	208.33	284.09
0.4	40	1	65.67	74.47	124	0	206.67	233.96
0.5	34	0	56.67	54.84	70	0	116.67	112.90
0.6	18	0	30.00	26.87	66	0	110.00	98.51
0.7	12	1	19.00	15.44	28	0	46.67	38.36
0.8	8	1	12.33	9.39	12	0	20.00	15.58
0.9	6	0	10.00	7.41	9	0	15.00	11.11
1	7	2	9.67	6.43	2	0	3.33	2.41
1.1	3	2	3.00	1.51	2	2	1.33	0.34
1.2	3	2	3.00	1.41	0	0	0.00	0.00
1.3	3	3	2.00	0.35	1	1	0.67	0.12
1.4	0	0	0.00	0.00	0	0	0.00	0.00
1.5	3	1	4.00	2.28	0	0	0.00	0.00
1.6	0	0	0.00	0.00	0	0	0.00	0.00
1.7	0	0	0.00	0.00	0	0	0.00	0.00
1.8	2	2	1.33	0.15	0	0	0.00	0.00
1.9	0	0	0.00	0.00	0	0	0.00	0.00
2.3	0	0	0.00	0.00	0	0	0.00	0.00
2.5	1	1	0.67	0.04	0	0	0.00	0.00
2.6	1	1	0.67	0.04	0	0	0.00	0.00
2.8	1	1	0.67	0.03	0	0	0.00	0.00
4.2	1	1	0.67	0.00	0	0	0.00	0.00
Total	188	188	188.00	188.00	188	188	188.00	188.00
> 1V	18	18	18.00	18.00	18	18	18.00	18.00
> 2V	4	4	4.00	4.00	4	4	4.00	4.00

Table 7-2 (Sheet 2 of 2)
South Texas Unit 2 October 1998
EOC-6 Bobbin and Assumed BOC-7 Bobbin Distributions in SLB Leak Rate and Tube Burst Analyses

Voltage Bin	Steam Generator C				Steam Generator D			
	EOC - 6		BOC - 7		EOC - 6		BOC - 7	
	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD	Field Bobbin Indications	Indications Repaired	POD 0.6	POPCD
0.1	4	0	6.67	16.67	2	0	3.33	8.33
0.2	38	0	63.33	111.76	25	0	41.67	73.53
0.3	96	1	159.00	217.18	84	0	140.00	190.91
0.4	109	0	181.67	205.66	71	1	117.33	132.96
0.5	82	1	135.67	131.26	64	0	106.67	103.23
0.6	60	0	100.00	89.55	29	0	48.33	43.28
0.7	24	1	39.00	31.88	29	0	48.33	39.73
0.8	18	0	30.00	23.38	12	0	20.00	15.58
0.9	10	0	16.67	12.35	11	0	18.33	13.58
1	5	0	8.33	6.02	5	0	8.33	6.02
1.1	2	1	2.33	1.34	1	1	0.67	0.17
1.2	3	3	2.00	0.41	2	2	1.33	0.27
1.3	1	1	0.67	0.12	1	1	0.67	0.12
1.4	1	1	0.67	0.10	0	0	0.00	0.00
1.5	0	0	0.00	0.00	2	2	1.33	0.19
1.6	0	0	0.00	0.00	1	1	0.67	0.09
1.7	1	1	0.67	0.08	0	0	0.00	0.00
1.8	0	0	0.00	0.00	0	0	0.00	0.00
1.9	1	1	0.67	0.07	0	0	0.00	0.00
2.3	1	1	0.67	0.05	1	1	0.67	0.05
2.5	0	0	0.00	0.00	0	0	0.00	0.00
2.6	0	0	0.00	0.00	0	0	0.00	0.00
2.8	0	0	0.00	0.00	0	0	0.00	0.00
4.2	0	0	0.00	0.00	0	0	0.00	0.00
Total	188	188	188.00	188.00	188	188	188.00	188.00
> 1V	18	18	18.00	18.00	18	18	18.00	18.00
> 2V	4	4	4.00	4.00	4	4	4.00	4.00

Table 7-3
South Texas Unit 2 October 1998
Voltage Distribution Projection for EOC - 7

Voltage Bin	Steam Generator A		Steam Generator B		Steam Generator C		Steam Generator D	
	Projected Number of Indications at EOC - 7							
	POD 0.6	POPCD	POD 0.6	POPCD	POD 0.6	POPCD	POD 0.6	POPCD
0.1	0.11	0.18	1.55	3.20	1.15	2.41	0.21	0.44
0.2	3.70	5.55	18.90	33.62	13.20	23.72	4.08	7.57
0.3	22.10	29.83	85.52	131.48	59.61	90.78	28.96	45.17
0.4	48.76	60.25	159.76	210.61	123.79	161.21	80.14	107.40
0.5	55.20	61.48	174.92	204.68	151.59	174.61	104.14	125.41
0.6	46.41	46.69	140.98	147.69	135.69	140.06	99.48	107.72
0.7	32.64	30.27	103.38	98.09	100.50	94.93	77.26	76.40
0.8	21.99	19.04	66.45	58.96	64.17	56.60	55.61	50.89
0.9	15.53	12.66	37.90	32.04	39.00	32.48	38.18	32.73
1.0	11.39	8.67	20.44	16.62	23.56	18.74	25.31	20.69
1.1	8.15	5.72	10.80	8.53	13.83	10.59	15.92	12.57
1.2	5.51	3.52	5.60	4.32	7.79	5.68	9.35	7.15
1.3	3.72	2.17	3.00	2.33	4.41	3.03	5.29	3.96
1.4	2.94	1.84	1.85	1.52	2.73	1.80	3.10	2.24
1.5	2.61	1.80	1.25	1.07	1.85	1.19	2.10	1.48
1.6	2.08	1.39	0.82	0.70	1.31	0.80	1.60	1.08
1.7	1.54	0.95	0.53	0.45	0.93	0.52	1.18	0.75
1.8	1.19	0.76	0.38	0.36	0.69	0.38	0.98	0.71
1.9	1.07	0.77	0.30	0.29	0.55	0.30	0.87	0.71
2.0	0.84	0.57	0.03	0.05	0.44	0.13	0.64	0.50
2.1	0.62	0.38	0.00	0.00	0.34	0.00	0.45	0.32
2.2	0.44	0.22	0.00	0.00	0.26	0.00	0.31	0.18
2.3	0.34	0.13	0.70	0.00	0.20	0.70	0.23	0.11
2.4	0.30	0.09	0.00	0.70	0.09	0.00	0.19	0.09
2.5	0.35	0.15	0.00	0.00	0.00	0.00	0.26	0.24
2.6	0.59	0.44	0.00	0.00	0.00	0.00	0.46	0.49
2.7	0.60	0.22	0.00	0.00	0.70	0.00	0.37	0.11
2.8	0.52	0.00	0.30	0.30	0.00	0.30	0.00	0.70
2.9	0.38	0.70	0.00	0.00	0.30	0.00	0.70	0.00
3.0	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.30
3.1	0.21	0.30	0.00	0.00	0.00	0.00	0.30	0.00
3.2	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.3	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.8	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.5	0.30	0.00			0.00	0.00	0.00	0.00
TOTAL	293.32	296.74	835.36	957.61	748.68	820.96	557.67	608.11
> 1 V	35.49	22.12	25.56	20.62	36.42	25.42	44.30	33.69
> 2 V	5.84	2.63	1.00	1.00	1.89	1.00	3.27	2.54

Table 7-4

South Texas Unit 2 October 1998
Comparison of Predicted and Actual EOC-6 Voltage Distributions

Voltage Bin	Steam Generator A		Steam Generator B		Steam Generator C		Steam Generator D	
	Number of Indications							
	EOC-6 Prediction POD = 0.6	EOC-6 Actual	EOC-6 Prediction POD = 0.6	EOC-6 Actual	EOC-6 Prediction POD = 0.6	EOC-6 Actual	EOC-6 Prediction POD = 0.6	EOC-6 Actual
0.1	0.0	0	1.0	2	0.1	4	0.4	2
0.2	0.2	5	10.1	59	2.7	38	10.1	25
0.3	1.9	40	36.1	125	11.6	96	41.6	84
0.4	10.4	40	73.8	124	27.9	109	89.7	71
0.5	23.4	34	105.0	70	53.9	82	106.4	64
0.6	36.0	18	107.8	66	69.0	60	81.2	29
0.7	43.7	12	86.4	28	73.0	24	49.2	29
0.8	43.5	8	59.3	12	61.6	18	27.3	12
0.9	37.9	6	36.9	9	47.6	10	12.9	11
1.0	30.8	7	20.9	2	34.3	5	5.8	5
1.1	23.9	3	11.6	2	23.0	2	3.5	1
1.2	18.4	3	6.1	0	14.5	3	3.2	2
1.3	14.1	3	3.0	1	8.4	1	2.2	1
1.4	11.0	0	1.4	0	4.6	1	1.4	0
1.5	8.4	3	0.8	0	2.4	0	0.8	2
1.6	6.2	0	0.7	0	1.0	0	0.0	1
1.7	4.3	0	1.0	0	0.0	1	0.7	0
1.8	2.9	2	0.9	0	0.7	0	0.3	0
1.9	1.9	0	0.6	0	0.3	1	0.0	0
2.0	1.2	0	0.5	0	0.0	0	0.0	0
2.1	0.7	0	0.2	0	0.0	0	0.0	0
2.2	0.1	0	0.0	0	0.0	0	0.0	0
2.3	0.7	0	0.7	0	0.0	1	0.0	1
2.5	0.3	1	0.3	0	0.0	0	0.0	0
2.6	0.0	1	0.0	0	0.0	0	0.0	0
2.8	0.0	1	0.0	0		0	0.0	0
4.2		1	0.0	0		0		0
TOTAL	321.7	188	565.0	500	436.7	456	436.7	340
> 1 V	94.1	18	27.6	3	54.9	10	12.1	8
> 2 V	1.8	4	1.2	0	0.0	1	0.0	1

Figure 7-1
Generic POPCD Distribution Based on 15 Inspections in 8 Plants
[Presented in EPRI Report NP-7480, Addendum-1]

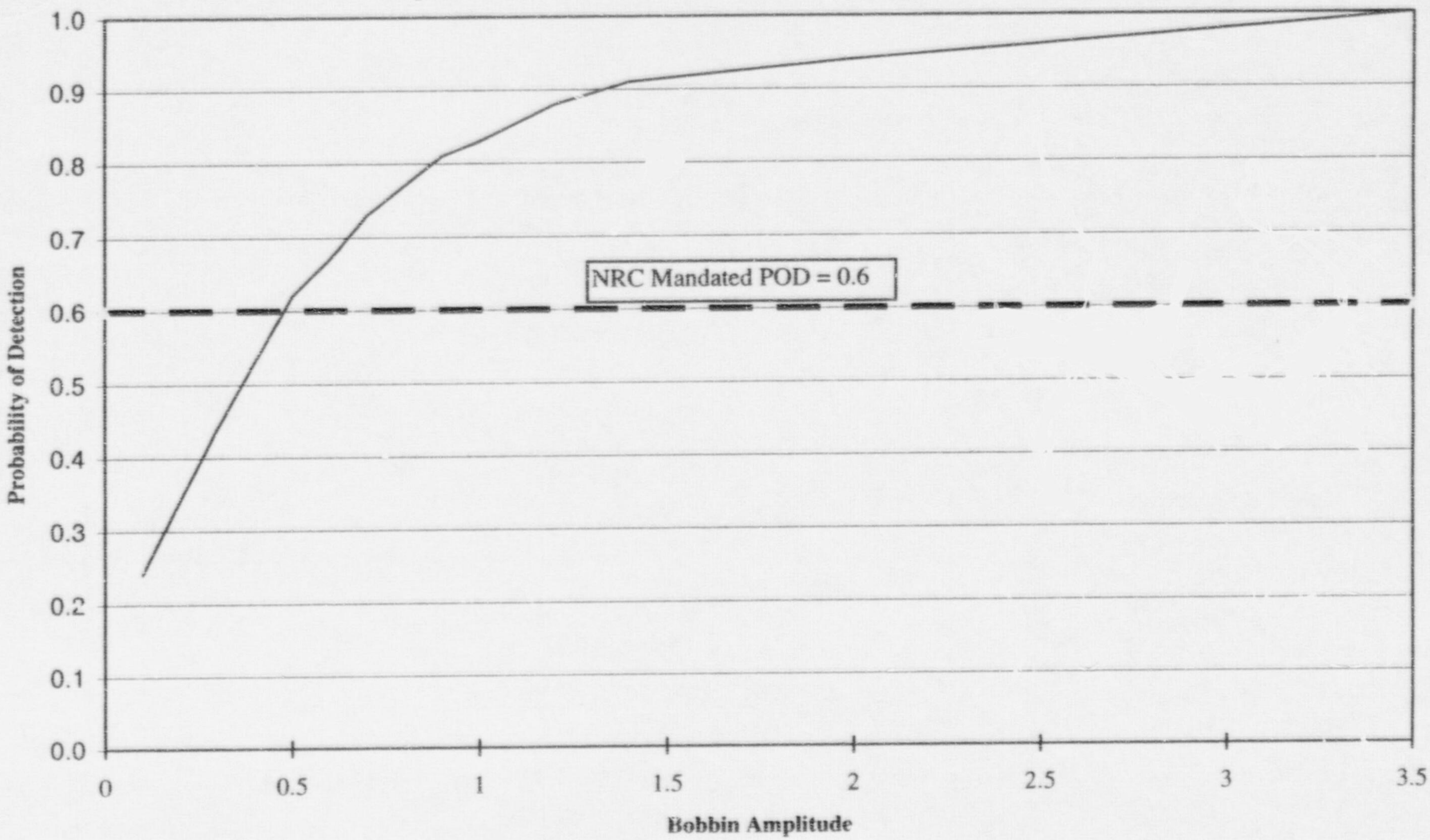


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Figure 7-2

South Texas Unit 2 SG-A
Predicted Bobbin Voltage Distribution for Cycle 7
Combined Data for Hot and Cold Leg Indications

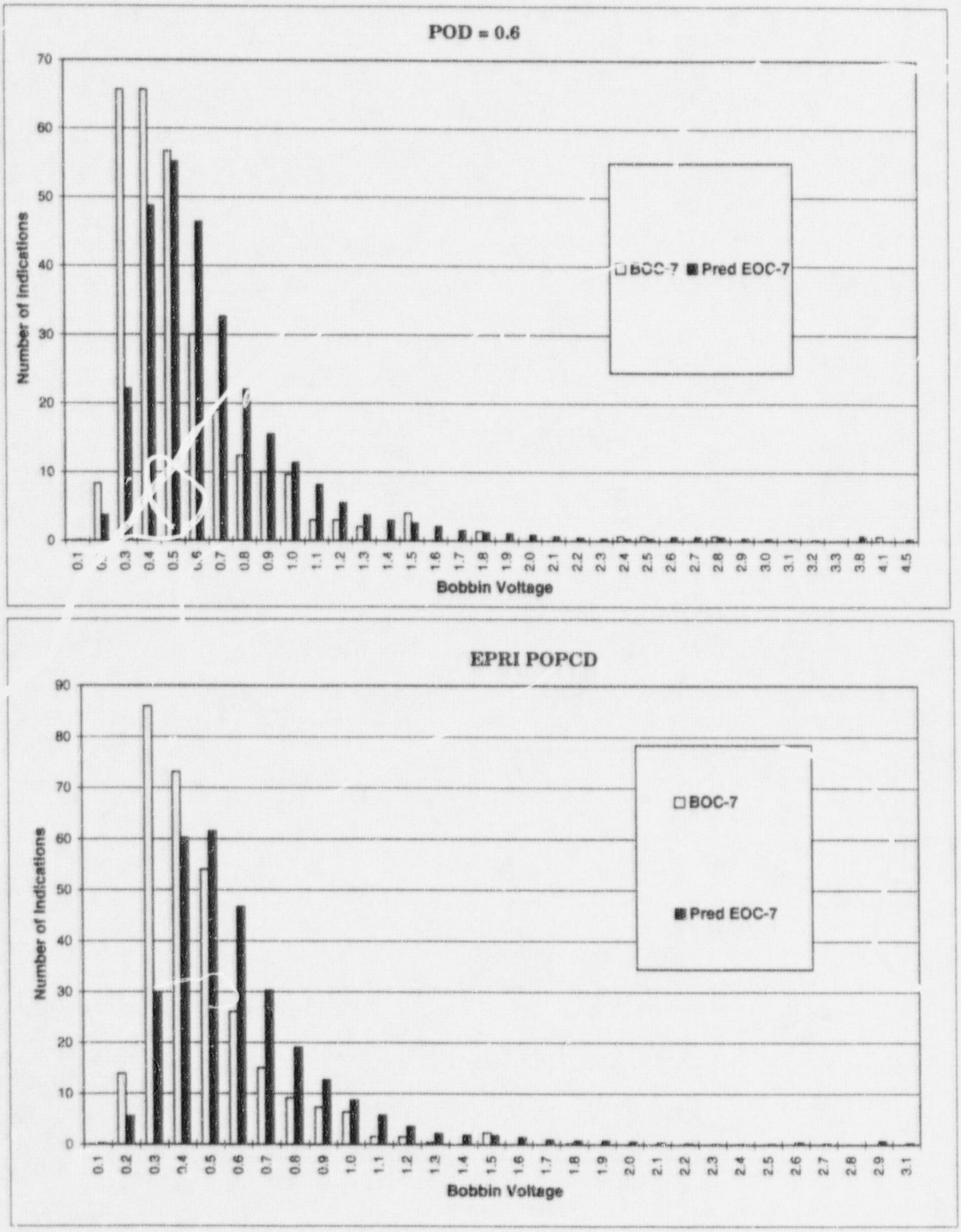
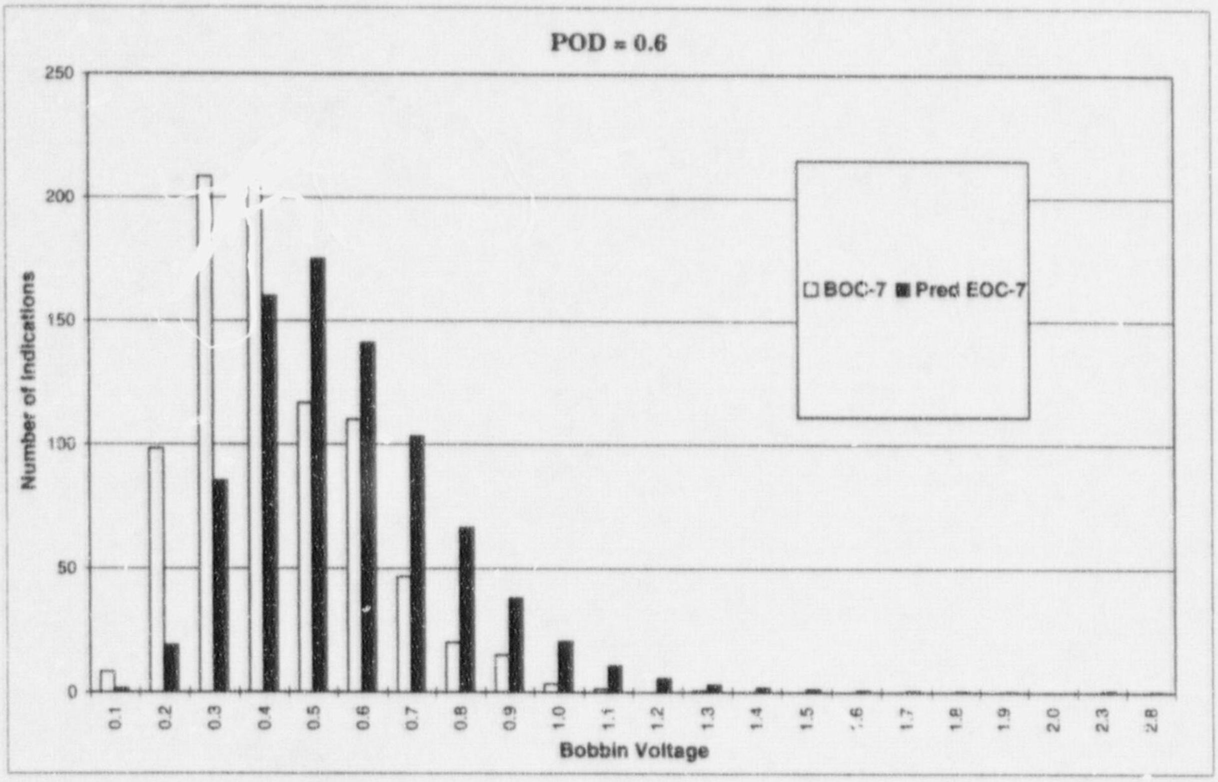


Figure 7-3
South Texas Unit 2 SG-B
Predicted Bobbin Voltage Distribution for Cycle 7



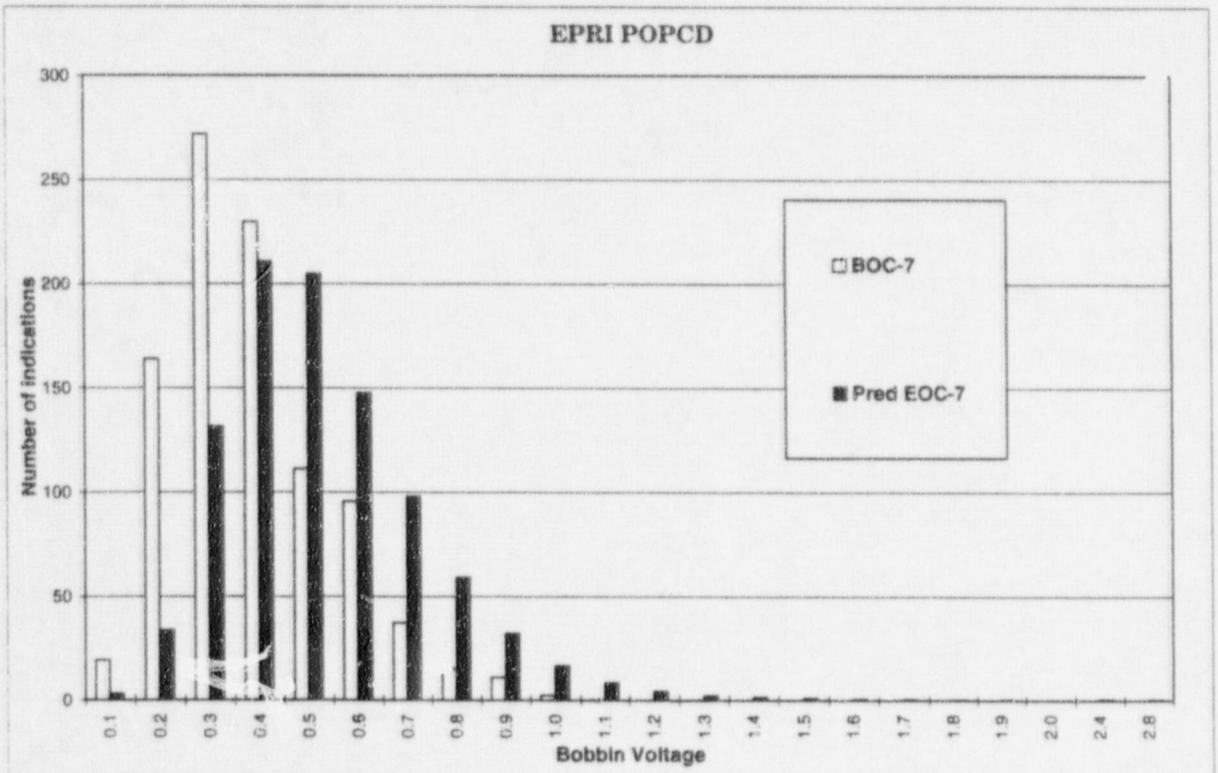
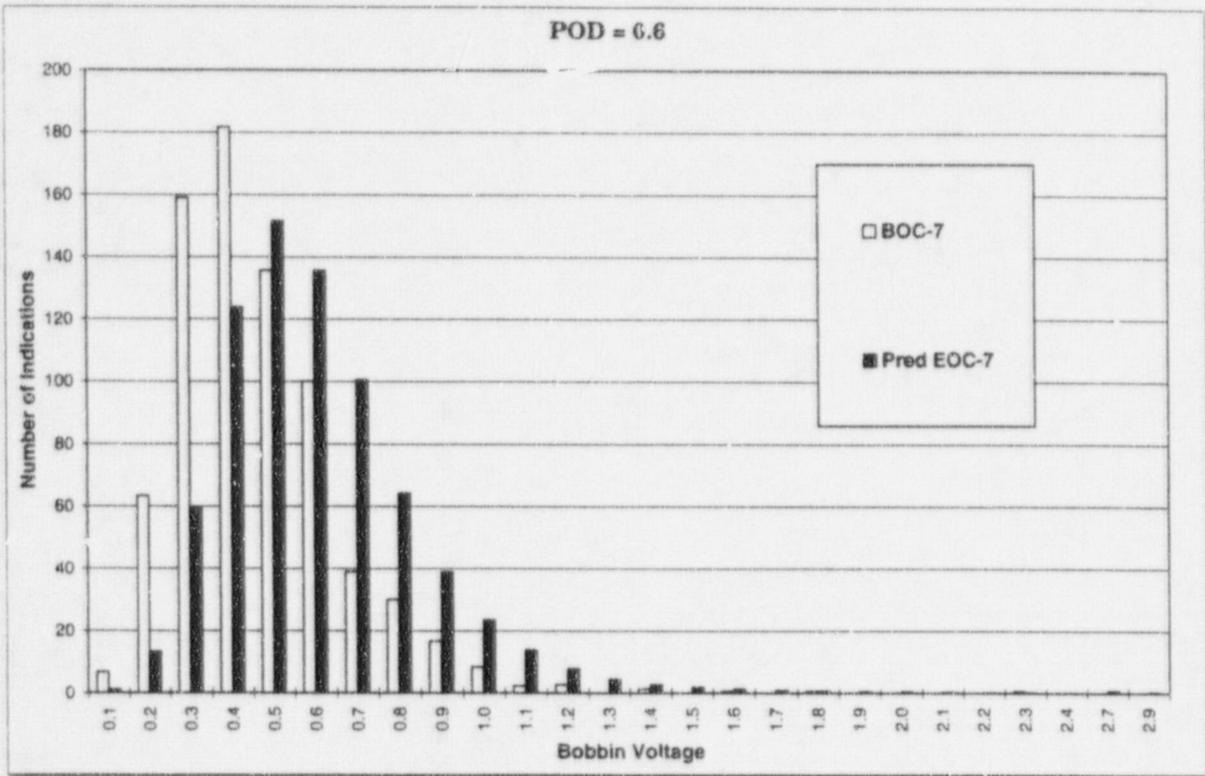


Figure 7-4
South Texas Unit 2 SG-C
Predicted Bobbin Voltage Distribution for Cycle 7



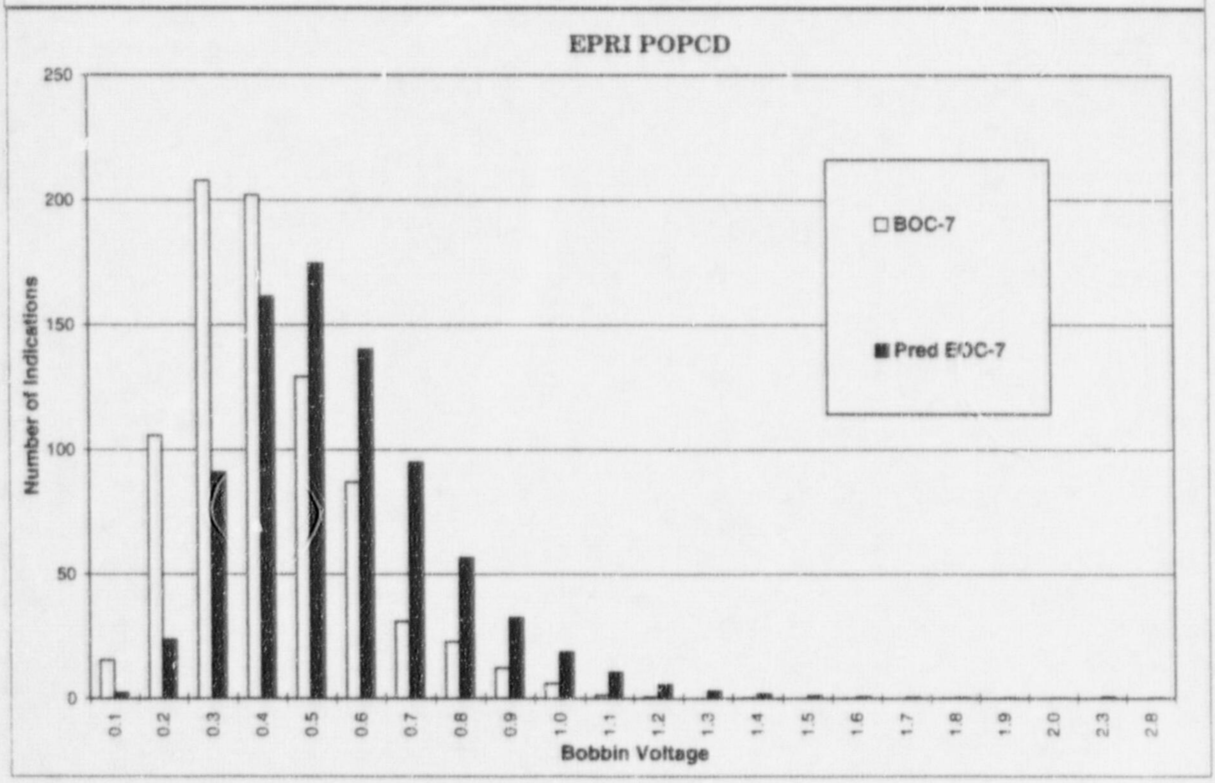
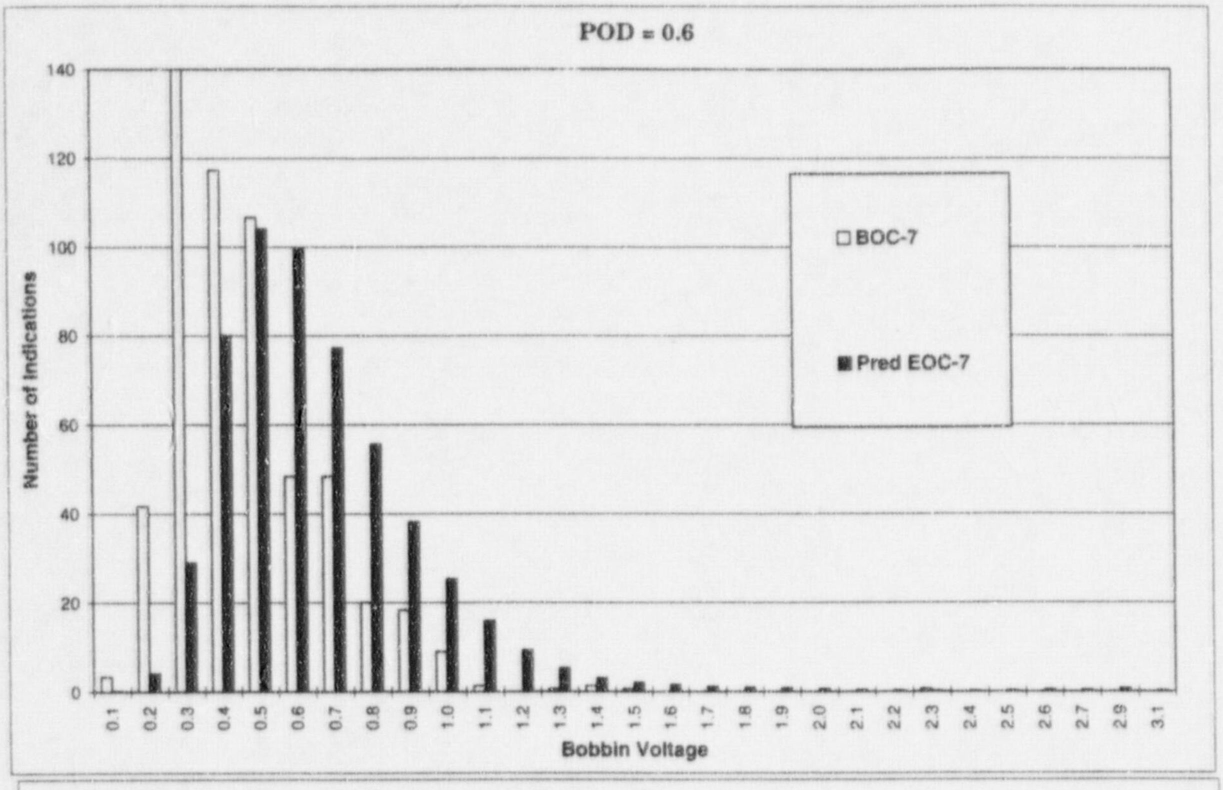


Figure 7-5
South Texas Unit 2 SG-D
Predicted Bobbin Voltage Distribution for Cycle 7



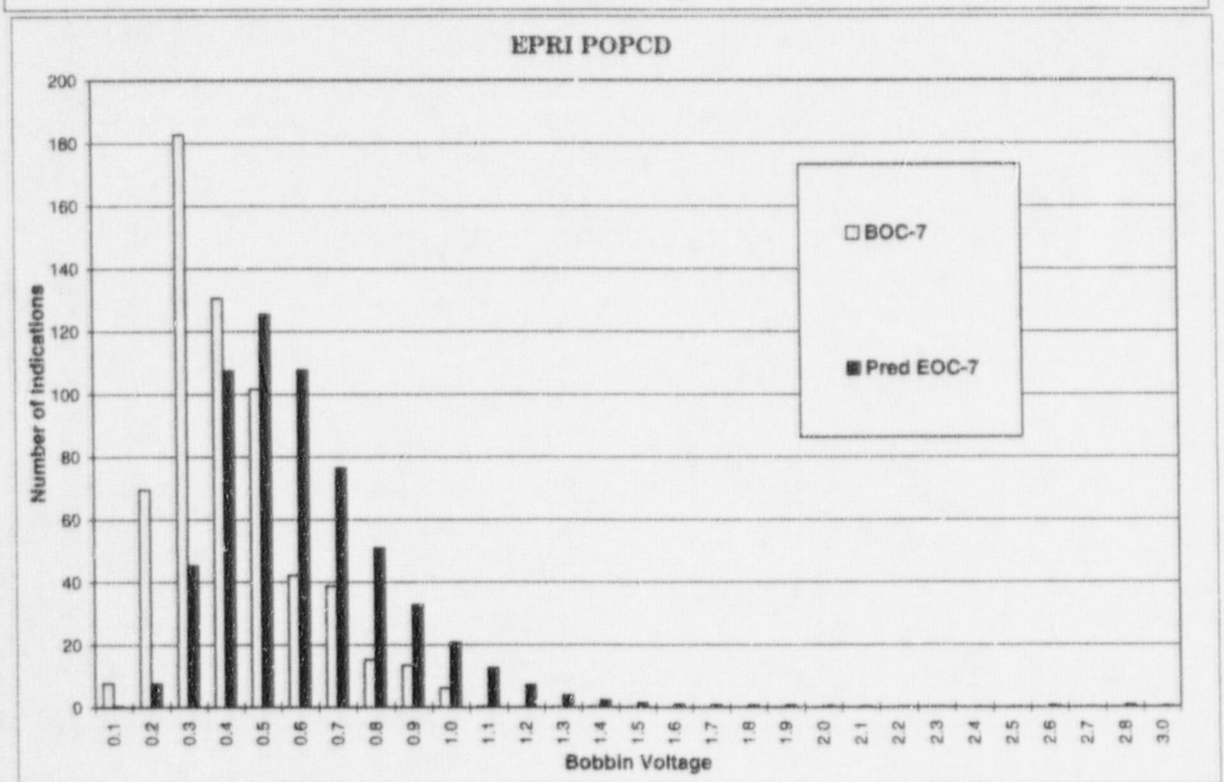
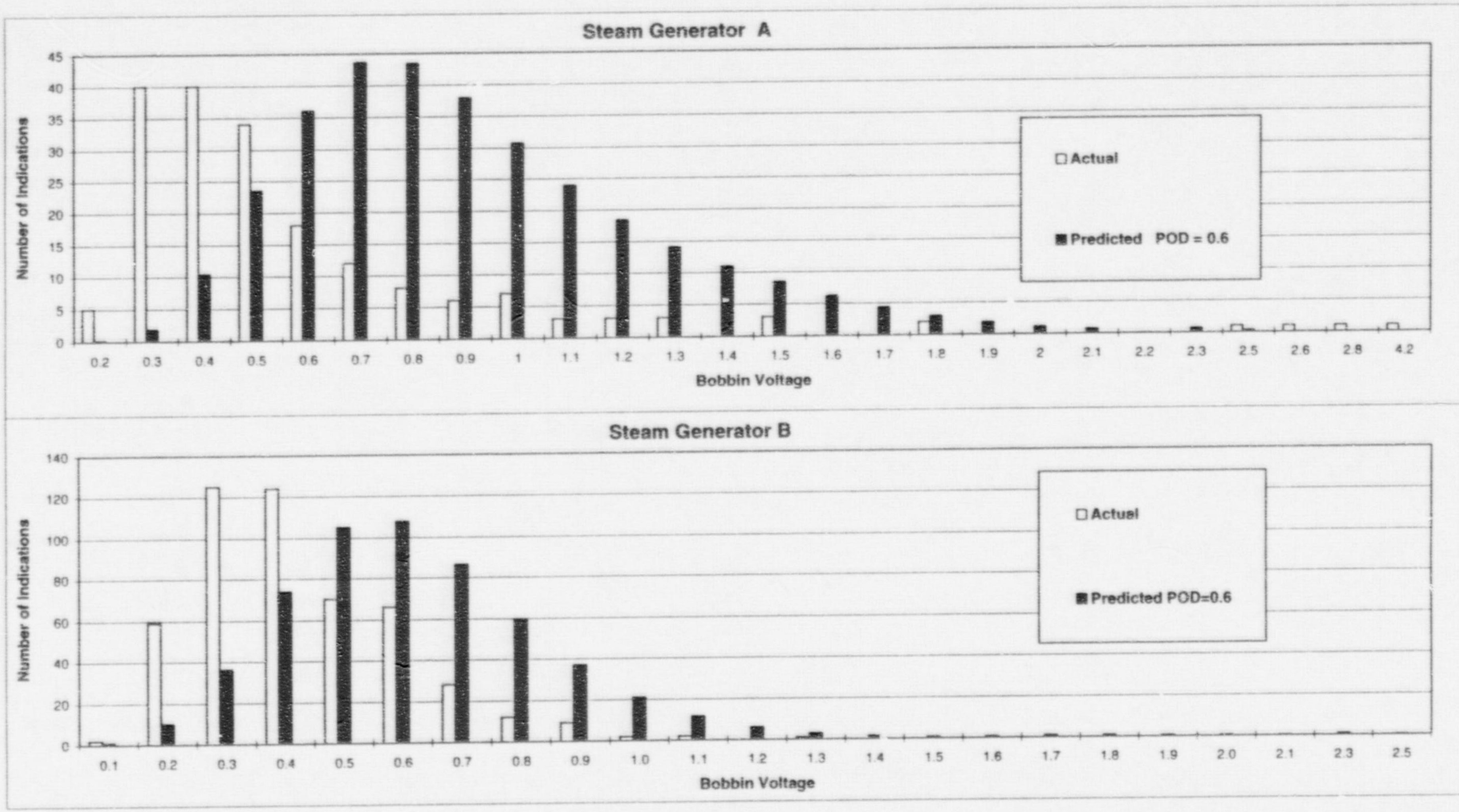
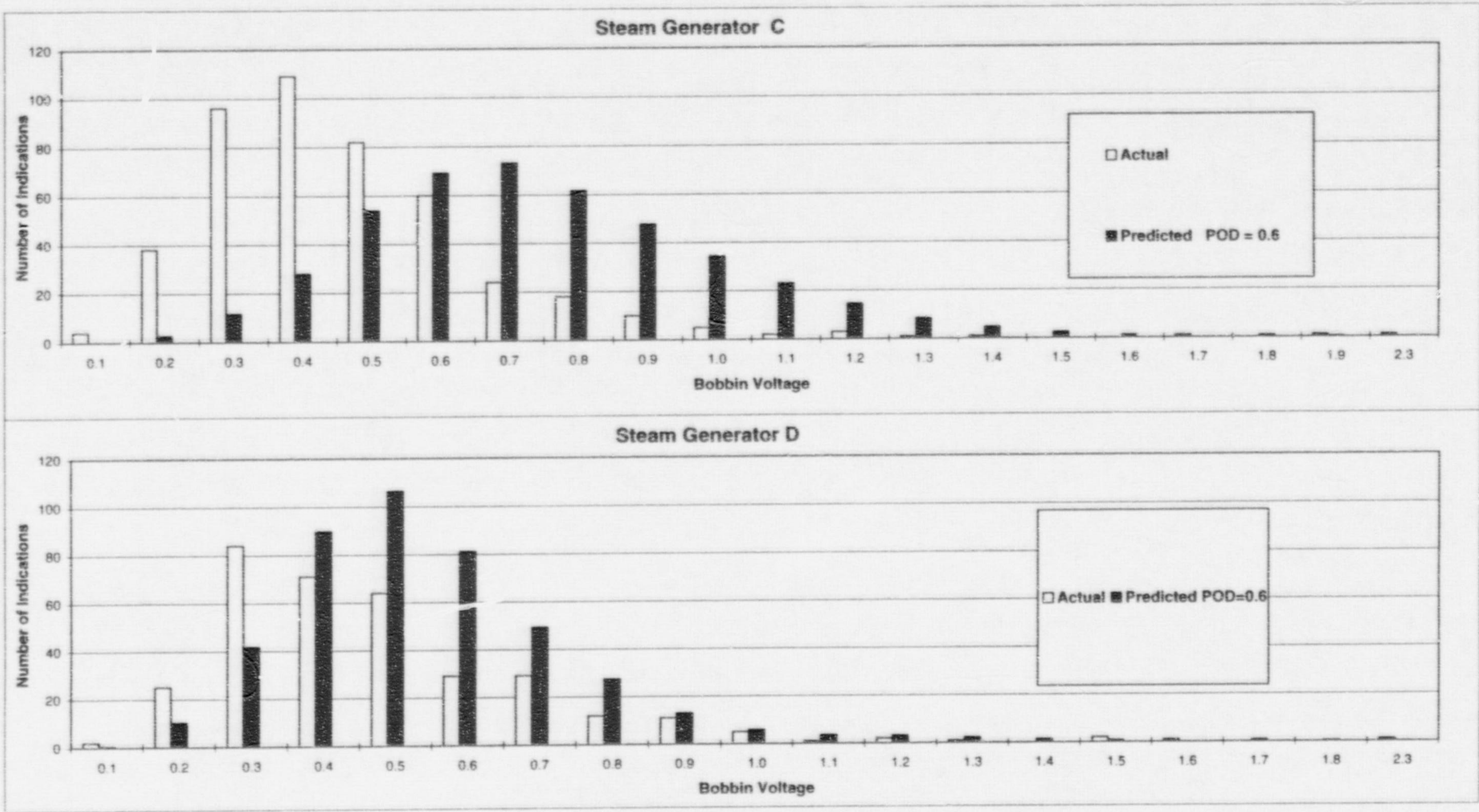


Figure 7-6
South Texas Unit 2 October 1998
Bobbin Voltage Distributions for Cycle 6



Predcomp Fig_6 1/11/99 4:58 PM

Figure 7-7
South Texas Unit 2 October 1998
Bobbin Voltage Distributions for Cycle 6



8.0 SLB Leak Rate and Tube Burst Probability Analyses

This section presents results of analyses carried out to predict the leak rates and tube burst probabilities for postulated SLB conditions using the actual voltage distributions from EOC-6 inspection as well as for the projected EOC-7 voltage distributions. The methodology used in these analyses is described in Section 6.0. SG-A with the largest total number of indications over 1 volt is expected to yield the limiting SLB leak rate and burst probability for Cycle 6.

8.1 Leak Rate and Tube Burst Probability for EOC-6

Analyses to calculate EOC-6 SLB leak rates and tube burst probabilities were performed using the actual bobbin voltage distributions presented in Table 7-2. The results of Monte Carlo calculations are summarized in Table 8-1. A comparison of the EOC-6 actuals in Table 8-1 with the corresponding predictions presented in Reference 9-2, indicates the following.

a) SG-A was predicted to be the limiting steam generator for EOC-6 based on a voltage distribution projection performed using the EOC-5 outage. SG-A was confirmed to have the highest tube leak rate and burst probability based on actual EC bobbin measurements for EOC-6.

b) For the limiting SG-A, leak rate and tube burst probability predictions based on the EOC-5 inspection data are below those obtained with the actual measured EOC-6 voltages. However, the magnitude of the differences are small ($\sim 2\times10^{-4}$ for burst probability and 0.02 gpm for leakage) and they are about 2 orders of magnitude below the acceptance limits for leak rate and tube burst probability.

c) Leak rate and tube burst probability predictions for all four SGs based upon EOC-6 actual bobbin measurements are well within the allowable limits.

In summary, the limiting values for SLB leak rate (0.032 gpm) and tube burst probability (3.8×10^{-4}) obtained using the actual measured voltages are nearly two orders of magnitude below the allowable Cycle 7 SLB leakage limit of 15.4 gpm (room temperature) and the NRC reporting guideline of 10^{-2} for the tube burst probability.

8.2 Leak Rate and Tube Burst Probability for EOC-7

Calculations to predict SLB leak rate and tube burst probability for the limiting steam generator in South Texas Unit-2 at the EOC-7 condition were carried out using two values for POD: 1) NRC required constant value of 0.6, 2) voltage dependent EPRI POPCD distribution. Projected results for EOC-7 conditions are summarized in Table 8-2. With the standard calculation methodology presented in Reference 9-3 and a constant POD of 0.6, the largest EOC-7 SLB leak rate projected is 3.3×10^{-2} gpm (room temperature), and it is predicted for SG-A which has the largest number of indications over 1 volt returned to service for Cycle 7 operation. This limiting SLB leak rate value is nearly 3 orders of magnitude below the allowable SLB leakage limit for Cycle 7 of 15.4 gpm (room temperature). The highest tube burst probability, also predicted for SG-A, is 4.2×10^{-4}, and it is about $1/25^{th}$ of the NRC reporting guideline of 10^{-2}.

With EPRI POPCD total number of indications predicted are higher than those for POD=0.6. The reason for this is that below about 0.5 volt, the detection probability calculated from EC inspection data could be significantly below 0.6 as shown by the EPRI POPCD distribution in Table 8-1 and Figure 8-1. Nearly 80% percent of the indications returned to service for Cycle 7 operations are below 0.5 volt. However, SLB leak rate and burst probability values more strongly influenced by indications over 1 volt and therefore leak and burst values based on EPRI POPCD are all below those corresponding to POD=0.6.

As noted in Section 4.2, the Cycle 6 growth data for SG-A seems to show a dependency on BOC-7 voltage since larger growths (say, over 0.5 volt) occurred at BOC voltages greater than the mean BOC voltage for the SG. To examine the impact of the voltage-dependent growth trend observed for SG-A on tube integrity projections, SLB leak rate and tube burst probability projection for the EOC-7 condition for SG-A was carried using the methodology recommended in Reference 9-4 and the results are included in Table 8.2. The Cycle 6 growth data for SG-A was divided into two bins: ≤ 0.4 volt and over 0.4 volt. Since there only 188 indications in the Cycle 6 growth data for SG-A, the Reference 9-4 recommendation that growth bins should include at least 200 indications could not be met, and therefore the voltage-dependent growth distribution utilized herein is conservative. As shown in Table 8-2, with a voltage-dependent growth assumption, the EOC-7 SLB leak rate prediction for SG-A increased from 3.3×10^{-2} to 4.0×10^{-2}, and the corresponding tube burst probability increased from 4.2×10^{-4} to 5.5×10^{-4}. It is evident that the magnitude of increase in both SLB leak rate and tube burst probability are small in comparison to their 1 to 2 orders of magnitude margins relative to their acceptance limits.

Additional leak rate and tube burst pressure data are available from the tube specimens pulled during the recent inspection. An evaluation of the impact of the new data on the leak and burst correlations, described in Section 3.3, indicated that the new data would not significantly affect tube burst probability and the SLB leak rate may increase slightly. In accordance with the NRC-NEI protocol for determining whether the voltage-based repair criteria leak and burst database should be updated to include the latest data, EOC-7 leak rate and tube burst probability calculations for SG-A were repeated using correlations developed in Section 3.3 including new data, and these results are also included in Table 8.2. While the tube burst probability essentially remains the same, inclusion of the recent South Texas Unit-2 pulled tube data in the leak and burst database increases SLB leak rate from 3.3×10^{-2} to 4.5×10^{-2}. Again, the increase in the SLB leak rate is negligibly small in comparison to the margin to the allowable leak rate

In summary, SLB leak rates and tube burst probabilities predicted for EOC-7 are 1 or 2 orders of magnitude below their respective limits.

Table 8-1
South Texas Unit-2 1998 EOC- 6 Outage
Summary of Calculations of Tube Leak Rate and Burst Probability
Based on Actual Bobbin Voltage

Steam Generator	POD	Number of Indications(1)	Max. Volts(2)	Burst Probability		SLB Leak Rate (gpm)(3)
				1 Tube	1 or More Tubes	
EOC - 6 Projections Reported in Reference 9-2						
A	0.6	321.7	2.5	1.7×10^{-4}	1.7×10^{-4}	1.4×10^{-2}
B	0.6	565	2.5	9.0×10^{-5}	9.0×10^{-5}	5.5×10^{-3}
C	0.6	436.7	1.9	6.0×10^{-5}	6.0×10^{-5}	4.2×10^{-3}
D	0.6	436.7	1.8	2.4×10^{-5}	2.4×10^{-5}	1.3×10^{-3}
EOC-6 Actuals						
A	1	188	4.1	3.8×10^{-4}	3.8×10^{-4}	3.2×10^{-2}
B	1	500	1.3	2.5×10^{-5}	2.5×10^{-5}	1.8×10^{-4}
C	1	457	2.3	5.8×10^{-5}	5.8×10^{-5}	2.0×10^{-3}
D	1	340	2.3	1.2×10^{-5}	1.2×10^{-5}	4.6×10^{-4}

Notes:

(1) Number of indications adjusted for POD.

(2) Voltages include NDE uncertainties from Monte Carlo analyses and exceed measured voltages.

(3) Equivalent volumetric rate at room temperature.

Table 8-2
South Texas Unit-2 October 1998 Outage
Summary of Projected Tube Leak Rate and Burst Probability
for EOC-7 - 250k Simulations

Steam Generator	POD	No. of Indic-ations[1]	Max. Volts[2]	Burst Probability		SLB Leak Rate (gpm)[3]	Comments
				1 Tube	1 or More Tubes		
EOC - 8 PROJECTIONS							
A	0.6	293.3	4.5	4.2×10^{-4}	4.2×10^{-4}	3.3×10^{-2}	Standard leak rate and tube burst probability methodology Addendum-2 database
B		835.3	2.8	7.8×10^{-5}	7.8×10^{-5}	2.7×10^{-3}	
C		749.3	2.9	8.8×10^{-5}	8.8×10^{-5}	5.2×10^{-3}	
D		557.7	3.1	1.2×10^{-4}	1.2×10^{-4}	8.2×10^{-3}	
A	0.6	293.3	4.6	5.5×10^{-4}	5.5×10^{-4}	4.0×10^{-2}	Voltage-dependent growth
A		293.3	4.5	4.4×10^{-4}	4.4×10^{-4}	4.5×10^{-2}	Updated database with present pulled tube data included
A	POPCD	296.8	3.1	1.1×10^{-4}	1.1×10^{-4}	6.8×10^{-3}	Standard leak rate and tube burst probability methodology Addendum-2 database
B		957.6	2.8	5.8×10^{-5}	5.8×10^{-5}	2.5×10^{-3}	
C		821.0	2.8	5.3×10^{-5}	5.3×10^{-5}	2.8×10^{-3}	
D		608.1	3.0	3.1×10^{-5}	3.1×10^{-5}	6.4×10^{-3}	

Notes
(1) Number of indications adjusted for POD.
(2) Voltages include NDE uncertainties from Monte Carlo analyses and exceed measured voltages.
(3) Equivalent volumetric rate at room temperature.

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9.0 References

9-1 NRC Generic Letter 95-05, "Voltage-Based Repair Criteria for the Repair of Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking," USNRC Office of Nuclear Reactor Regulation, August 3, 1995.

9-2 SG-98-01-004, "South Texas Project (STP) Unit-2, Technical Justification for License Amendment to Implement NRC Generic Letter GL 95-05 Voltage-Based Repair Criteria Steam Generator Tube ODSCC," Westinghouse Company, January 23, 1998.

9-3 WCAP-14277, Revision 1, "SLB Leak Rate and Tube Burst Probability Analysis Methods for ODSCC at TSP Intersections", Westinghouse Nuclear Services Division, December.1996.

9-4 EPRI Report NP 7480-L, Addendum 2, "Steam Generator Tubing Outside Diameter Stress Corrosion Cracking at Tube Support Plates Database for Alternate repair Limits," Electric Power Research Institute, April 1998.

9-5 "Evaluation of Proposed Update to SGDSM Database and Modifications to the Methodology to Assess Steam Generator Tubing Outside Diameter Stress Corrosion Cracking," G. C. Lainas (USNRC) to D. J. Modeen (NEI), November 20, 1998.

9-6 SG-97-12-006, "South Texas Unit-1, Cycle 8 Voltage-Based Repair Criteria Report," Westinghouse Electric Company, December, 1997.

9-7 Letter from B. W. Sheron, Nuclear Regulatory Commission, to A. Marion, Nuclear Energy Institute, dated February 9, 1996.

9.0 References

9-1 NRC Generic Letter 95-05, "Voltage-Based Repair Criteria for the Repair of Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking," USNRC Office of Nuclear Reactor Regulation, August 3, 1995.

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